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EDITED BY

FRANK CARNEY

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FRANK CARNEY
Permanent Secretary Denison Scientific Association

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FOREWORD

Greeting to the Ohio Academy of Science

Eighteenth Annual Meeting, Nov. 27, 1908

By

PRESIDENT EMORY W. HUNT

It gives me pleasure on behalf of Denison University to welcome this Academy. It is our hope that you may find the atmosphere of the college congenial to your spirit and purpose. You cannot meet in this building without becoming assured that the trustees and friends of Denison give hearty sympathy and support to the work of its Scientific Departments.

We believe in the truth. We believe it enough so that we are not nervous about it. We believe that the world of truth is consistent. Its various departments are not at war with each other. Apparent conflict means a faulty reading of the facts somewhere. Nothing that is true can ever obscure a faith that is real. If it is true, no matter who says it, we want to know it, and to surrender our lives to it.

Moreover, we are persuaded that every investigator and teacher needs all the light that is available. The man of truth opens wide the windows of his mind in every direction. He does not shut his mind to the light from above. The true teacher is reverent.

The teacher needs also the side-lights upon truth, the special illumination and inspiration, the enrichment of his own life, which come only from original research and independent investigation. However, the teacher must never permit himself to forget that his objective is a personality, not a "thesis." The real teacher longs to inspire in others the spirit of research, and is willing to take the trouble patiently to inculcate in them right basal methods.

One who is mentally alive enough to teach, will inevitably be extending his lines of inquiry into new territory. If he does not do this, his own mental life will stagnate and he will lose teaching power.

With this trust in the truth, and this loyalty to the light, we welcome you as fellow-seekers for truth, who are also trying to guide others into the truth.

PRE-WISCONSIN DRIFT IN THE FINGER LAKE REGION OF NEW YORK.[1]

FRANK CARNEY.

CONTENTS.

INTRODUCTION.

With old drift on Long Island,[2] in New Jersey,[3] and in northwestern Pennsylvania,[4] it is very likely that a line of old drift should connect these areas. If, however, these localities of old drift represent ice-work from separate dispersion centers, then the re-entrant angle not covered by this drift might include much of

[1] Reprinted from the *Journal of Geology*, vol. xv, No. 6, September-October, 1907.

[2] J. B. Woodworth, *New York State Museum Bulletin 48* (1901), pp. 618–70; M. L. Fuller, *American Geologist*, vol. xxxii (1903), pp. 308–12; A. C. Veatch, *Journal of Geology*, vol. xi (1903), pp. 762–76.

[3] R. D. Salisbury, Geological Survey of New Jersey, *Annual Report for 1893*, pp. 73, etc.; vol. v (1902), pp. 187–89; 751-782.

[4] F. Leverett, *Monograph XLI*, U. S. Geological Survey (1902), p. 228; L. H. Woolsey, *Beaver Folio*, No. 134 (Pennsylvania), U. S. Geological Survey (1905), p. 7.

New York state; but this supposition is hardly in harmony with accepted facts concerning the centers of ice-dispersion. Theoretical consideration, therefore, leads to the conclusion that in the Finger Lake region of New York the late Wisconsin drift sheet covers at least the ice-erosion remnants of older drift. Students of glacial geology have already tentatively presumed earlier glaciation in this region.[5]

That there has not already been reported some observed evidence of pre-Wisconsin drift in the Finger Lake region is doubtless due to one of two causes: workers may have felt that such drift should be highly weathered; or that at this distance north of the ice-margin erosion was so vigorous as to have removed the earlier drift. In all probability ice-erosion has removed most of the weathered horizon of the old drift, mingling it so thoroughly with fresh débris that it is not easily identified. In walking over the fields of the lake country one notes the presence of small bowlders which are very much weathered, bowlders that remind him of the general condition of stones in the areas of old drift; this is the most pertinent suggestion of the earlier glaciation of this region.

PRE-WISCONSIN DRIFT IN GENERAL.

The older drift sheets have been studied more thoroughly in the Mississippi basin than elsewhere; their chronological sequence is generally established on the degree of weathering exhibited. In the case of the Sub-Aftonian[6] and the Iowan,[7] the lithological content is made a discriminating feature; the absence of water-laid material is a feature usually emphasized in describing the Kansan drift,[8] whereas the blue or blue-gray color of the unweathered Illinoian is pointed out.[9] Where the formations of different sheets

[5] R. S. Tarr, *Journal of Geology*, vol. xiv (1906), pp. 18, 19; *Bulletin of the Geological Society of America*, vol. xvi (1905), p. 217; H. L. Fairchild, *ibid.*, p. 66.

[6] W. J. McGee, U. S. Geological Survey, *Eleventh Annual Report* (1891), p. 497.

[7] Chamberlin and Salisbury, *Geology*, vol. iii (1906), p. 384.

[8] *Ibid.*, p. 389.

[9] F. Leverett, *Monograph XXXVIII*, U. S. Geological Survey (1899), p. 28; *Monograph XLI* (1902), p. 272.

of drift are superposed, the distinctions may be more accurately recorded; but good sections of this imbrication are rare. Some contact sections, all from the Mississippi valley, are shown in Chamberlin and Salisbury, *Geology*, vol. iii, pp. 385–388.

Descriptions of old drift in western Pennsylvania and in New Jersey are perhaps more pertinent to the New York area. The old deposits in Pennsylvania, described by Leverett, are very stony, the pebbles usually showing water action; the bowlders are small and mostly of local origin; only a small amount of clay

FIG. 1. Southern portion of Bluff Point viewed from the east. The break or terrace in the frontal slope is a cusp which apparently correlates with Fairchild's Wayne overflow stage of glacial lake Hammondsport.

is present; there is slight evidence of bedding; the highly weathered condition of the drift, and the great amount of erosion it has suffered, are its conspicuous characteristics.[10]

The earlier drift in New Jersey is thus described: "The outer and older drift is deeply weathered from top to bottom, even where

[10] *Loc. cit.*, pp. 228, 229, 235.

it has a thickness of thirty feet, the greatest thickness it is known to possess. Its stones, so far as they are of decomposable rock, are decayed. From it most of the calcareous matter has been leached."[11] "The constitution of the drift is, in a general way, comparable to that of the younger drift. It contains materials of all grades, from huge bowlders to fine clay." "Limestone is rarely present. When the drift occurs in quantity, glaciated stones are by no means rare."[12] "It generally lacks all indication of structure, though foliation is to be seen in some of the deeper exposures." "In its constitution, and in the relations of its constituents, the drift corresponds with till."[13]

It should be noted, however, that Salisbury does not find the extramorainic drift in New Jersey uniform in the stage of weathering attained;[14] for this reason he suggests that, while most of it probably corresponds to the Kansan, it is possible that a younger pre-Wisconsin drift may be represented.[15]

Geographical factor. The above descriptions of drifts pertain to deposits more or less distant from central New York. The diversity in the stratigraphy and topography of northern North America introduces other considerations that may render these descriptions only partly applicable to other regions. Similarity of glacial deposits elsewhere may result only from identity, (*a*) in the stratigraphical terranes which furnished the débris; (*b*) in the period and conditions of weathering to which the débris was later exposed; (*c*) in the successions of ice-invasions; and (*d*) in the distance of the sections being compared from the termination of the particular sheet in question. It is evident, therefore, that in New England, New York, Pennsylvania and New Jersey specific drift-sheets may have somewhat different features than have been reported by investigators elsewhere.

TOPOGRAPHIC CONTROL OF THE EROSION AND DEPOSITION OF DRIFT.

In general. It is probable that the main dissection lines of the Finger Lake area even before the earliest glaciation were north-

[11] R. D. Salisbury, *Glacial Geology*, Geological Survey of New Jersey, vol. v (1902), p. 174.
[12] *Ibid.*, p. 188. [13] *Ibid.*, p. 757. [14] *Ibid.*, p. 769. [15] *Ibid.*, p. 782.

south valleys, the troughs of the present lakes, their tributaries; primary, secondary, and lesser, had developed a variety of transverse valleys. So in whatever direction the ice-mass moved there must have been localities, of rather limited extent, where ice-erosion was less active; also localities where the deposition of ice-débris was more pronounced. The combined effects of glacial erosion by the different invasions has not removed all the residual soil, the regolith of preglacial weathering.[16] Nor would a succeeding ice-sheet carry off all the drift deposited by a preceding invasion. Therefore it remains to inquire into the conditions most favorable to the deposition, and least favorable to the ice-erosion of former drift-sheets.

Deposition of drift. Aside from the ground moraine, the thickness and irregularity of which attest the heterogeneously distributed load which is being carried by the retreating ice, the localized deposits of débris represent in the first place a reaction of climatic factors that cannot be specifically determined; and, in the second place, the influence of topography upon the detailed outline of the ice-front. Climatic control evidently occasioned the pulsations of halt and retreat marked by the irregularly spaced belts of thickened drift; while the distribution of drift within the belts themselves is due both to local topography and to the topography of the areas passed over, in so far as these areas have contributed to the load of the ice. Furthermore, the broader outlines of these irregularly spaced belts reflect the reaction of the larger topographic features and the general direction of ice-movement from the dispersion centers; in consequence of this we have the moraines of ice-lobes. It follows, then, that no satisfactory control can at present be announced for the spacing of these belts.

Nevertheless, the influence of topography upon the detailed expression of the drift within the belt admits of closer definition. We would refer particularly to the following three conditions: (1) In a uniformly level area the ice-front would be without pro-

[16] H. L. Fairchild, *Bulletin of the Geological Society of America*, vol. xvi (1905), pp. 53–55; R. S. Tarr, *American Geologist*, vol. xxxiii (1904), p. 287, and F. Carney. The writer's unpublished notes on the Moravia (N. Y.) quadrangle afford further proof of the presence of preglacial weathered products in place.

nounced re-entrant angles; the drift would have a correspondingly even front, while it might have a very irregular surface. This type of topography is apt also to impose its characteristics upon the drift itself, as may be seen in the prairie regions. (2) In a section where the major valleys approach a position transverse to the general direction of ice-movement, the drift is found massed in these valleys, especially on their iceward sides; while in the

Fig. 2. An east-west section showing contact of the two drifts as exposed south of Dunning's Landing. The wavy, irregular line marks the upper surface of the blue till.

tributaries of these major valleys are moraine loops or dams. (3) If, however, the chief valleys approach a position parallel to the general direction of ice-movement, we find in them lateral moraines[17] blending into loops of drift in the bottoms of the valleys; while the secondary valleys may be partially clogged or buried with drift.

[17] R. S. Tarr, *Bulletin of the Geological Society of America*, vol. xvi, pp. 218, 219.

Erosion of drift. With this distribution of drift there must have been differential erosional effects produced by a second invasion of ice. Rather slight modifications would be effected under condition (1). The work of another ice-sheet passing over such an area is compressive quite as much as erosive; the more evenly the original drift is distributed, the less obstruction it offers to the progress of later ice; whereas, the weight of the overriding ice tends to compact this drift.

During the interval of deglaciation, stream-channeling, in the featureless topography of condition (1), proceeded slowly, since, to some extent at least, the streams were consequent. But with a larger lapse of time between the periods of glaciation this surface may have attained the relief of mature dissection, when it would present to the ice of the next invasion an opportunity for more effective corrasive work.

Each succeeding invasion would remove less of the previously deposited drift; it seems very probable that the resultant of several glacial invasions of such featureless topography is somewhat aggradational. And the final form given this drift depends upon the width and spacing of the moraine belts, if the ice were subject to varying relations of feeding and melting; or upon the thickness of drift deposited in an extensive sheet in case the feeding and melting factors were about balanced, the melting being slightly the stronger of the two. That the resulting forms due to the aggradational action of an ice-sheet overriding these two types of drift arrangement would not be identical seems reasonable.

The drift as described under condition (2) would suffer much less from a second invasion. The deposits in the major valleys—i.e., the valleys transverse to the direction in which the ice is moving—would be somewhat protected from erosion; the weight of the overriding ice would tend to indurate this drift. But the drift in valleys tributary to these, since they trend more in unison with the moving ice, must suffer much more from erosion. When such accumulations are rather thick, it is probable that a drumlinoid form is the resultant of degradation by a second invasion of ice, particularly in these tributary valleys.

The most marked erosional effects, however, are observed in

the old drift as distributed under condition (3). These valleys accord with the direction of ice-movement; if they open toward the approaching ice, greater obstruction is offered to its progress, hence greater erosion results; if they lead away from the feeding ice, the disturbance of the adjacent material may not be so marked. In the former case—i.e., the northward flaring valleys—the older drift, if not eroded, is apt to be deeply buried because of the in-

Fig. 3. Contact of the two drifts at Crosby. The broken line marks the upper surface of the compact blue till.

tense aggradational work of the valley lobes which characterized the margin of the waning ice-sheet. In the latter case the ice-erosion is less effective; the augmented ice-front drainage has degraded, shifted, or covered with later outwash the earlier deposits. The application of this principle probably varies inversely with the size or width of the valleys.

But the old drift in the minor valleys of condition (3) has suffered less from ice-erosion. The stage of development of these minor valleys, and their degree of transverseness to the moving ice are important factors in controlling the extent of ice-erosion in them.

Furthermore, under all these conditions we should find more old drift preserved in areas where during either pre- or interglacial time the drainage has suffered rejuvenation. The chances of such old drift being later revealed is greater in the transverse drainage lines of condition (3).

INHERENT CHARACTERISTICS OF OLD DRIFT THUS PRESERVED.

Compactness. The obvious resistance which this old drift offers to stream- or wave-cutting is its most characteristic feature. The pressure of the overriding ice-sheet has not only rendered such drift very compact, but there should be seen, particularly where the original deposits were fine in texture, a foliation due to the pressure. Lamination also might be contemporaneous with the formation of the deposits, but in any event it would be induced by great pressure. The effect of the superincumbent weight of a second ice-sheet should be noted, where the drift has been dissected into rather vertical cliffs, in the tendency of the pebbles and bowlders to overhang.

Color. In the region under discussion ice-erosion has had, in general, favorable conditions for effectiveness. The highly weathered zone of an earlier drift-sheet would be most disturbed or eroded by another invasion of ice, except in the case where ice-erosion had fallen short of the unweathered zone. The part of this earlier sheet remaining should have its original color, or at least the color which it had just previous to being overridden. Its present color need not necessarily be fresh or untarnished, but there is strong presumptive evidence that no color alteration has occurred since the retreat of the Wisconsin ice which furnished the débris for a protective burial of this older drift.

TOPOGRAPHY OF THE FINGER LAKE REGION.

General statement. The wide, prevailingly mature, lake-bearing valleys of central New York have received critical attention from workers in many lines of geology. Less attention, however, has been given to the more mature defunct valleys generally transverse to these. It is the unusual parallelism of the former, and their marked scenic beauty resulting from the variously interrupted

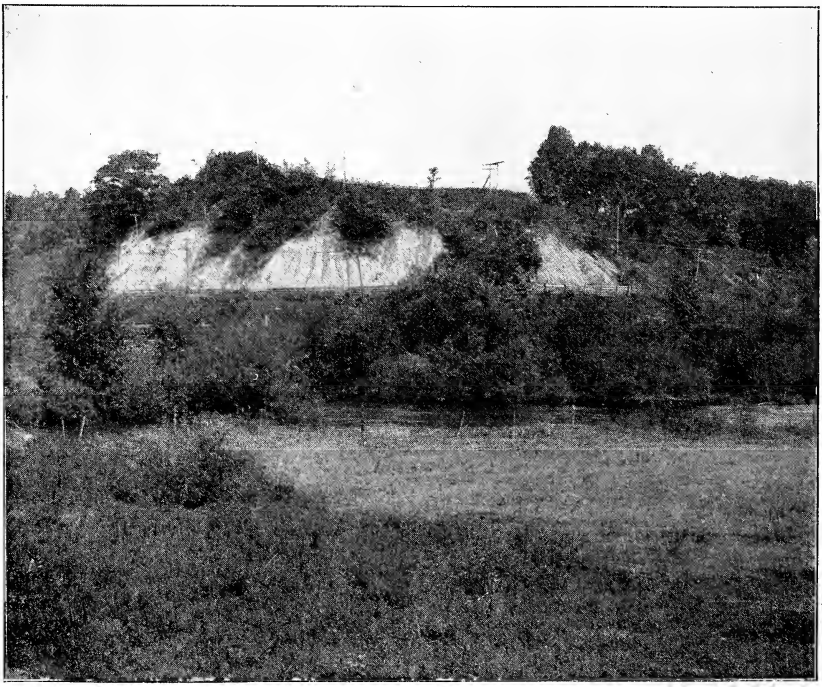


Fig. 4. The horizon of the Wisconsin drift is fairly well defined by the vegetation; the steep bare slope consists of very compact bluish till.

drainage history, that impel the comment of even the untrained observer. These long valleys opening to the north were occupied during the waning stage of the ice-sheet by valley glaciers[18] or by valley lobes which were relatively broad—a condition due to the iceward slope of the valleys.

[18] H. L. Fairchild, *American Journal of Science*, vol. vii (1899), pp. 252, 253.

Topography favors both ice-erosion and ice-stream aggradation. These conspicuous valleys, digital-like in arrangement, because of their general north-south trend, molded the basal ice of the deploying sheet into forms that expedited erosion. Furthermore, the fact that these valleys sloped toward the overriding wedges of ice facilitated the acquiring of a load which in turn augmented the erosive power of the ice up to the time when the amount of this load became so great that the basal ice lost in velocity; it then did little degradational work. In consequence of this differential erosion we find that approximately the southern thirds of these valleys are zones of ice-aggradation. Therefore, Professor Tarr's 900-foot-contour upper limit of most active erosion[19] defines a plain which dips into the Allegheny Plateau. The present attitude of this plain of erosion embodies some post-glacial deformation due to warping; but, neglecting the effects of this warping,[20] it is not likely that the plane would define a surface even parallel to its original attitude. Concerning the relation which this part of our continent bore to sea-level while the Wisconsin ice-sheet was active, we have insufficient data to warrant any but very general conclusions.

It is evident, then, that so far as the north-south valleys are concerned, exposures of the old drift are more apt to be found in a belt skirting the zone of heavy drift in the southern parts of the valleys; northward from this hypothetical belt erosion may have been very active, tending to remove the earlier deposits; southward, aggraded glacial rubbish has probably covered these deposits.

Few of the quite mature transverse valleys belonging to an interrupted but well-developed drainage cycle, above alluded to, have been described.[21] The more nearly transverse to ice-movement such valleys lie, the less ice-erosion they are subject to. Subsequent invasions of ice presumably have not removed much of the residual rock waste that escaped the earliest glaciation; nor would

[19] *Popular Science Monthly*, Vol. lxviii (1906), p. 389.

[20] G. K. Gilbert, U. S. Geological Survey, *18th Annual Report* (1896–1897). pp. 603–606; H. L. Fairchild, *Bulletin of the Geological Society of America*, Vol. x (1899), pp. 66–68.

[21] R. S. Tarr, *American Geologist*, Vol. xxxiii (1904), pp. 271–291; F. Carney, *Journal of Geography*, Vol. ii (1903), pp. 115–124.

an earlier deposit of drift suffer great erosion. Consequently valleys of this type are best fitted for the preservation of pre-Wisconsin drift. In the area covered especially by this paper two segments of such valleys, one extending eastward from the vicinity of Branchport (Penn Yan quadrangle), the other extending westward from Dresden (Ovid and Penn Yan quadrangles), have been studied.

LOCATION AND DESCRIPTION OF THE PRE-WISCONSIN DRIFT IN QUESTION.

First indication of such drift. In the area from Skaneateles to Keuka Lake the writer has often noted the highly weathered condition of smaller bowlders, both on the surface and in cuts in the drift. Later acquaintance with the older drift in Ohio has led him to give further attention to this observation. These scattered rather rotten crystallines may or may not suggest drift of different ages.

It is not likely that the first or even the second ice-invasion removed all the residual products of preglacial weathering. This much weathered material would constitute a larger part of the first than of any later drift-sheet. And from the fact that residual decay is noted beneath the Wisconsin drift[22] it follows that some preglacial weathered products have withstood several periods of ice-erosion.

Western slope of Bluff Point. This elongated ridge, drumlin-like in outline and slopes, peninsula-like in reference to the arms of the lake,[23] rises about 715 feet above the level of Keuka Lake. Its longer axis is meridional (fig. 1.) The striae below the 1100-foot contour measure S.65°–28° W. So on the western slope of the bluff the work of the ice was dragging and plucking rather than abrading. But if these striae represent only the final ice-motion in the area, then the work of the glacier may have been more vigorous

[22] H. L. Fairchild, *Bulletin of the Geological Society of America*, vol. xvi (1905), pp. 64, 65; R. S. Tarr, *American Geologist*, vol. xxxiii (1904), p. 286.

[23] James Hall, "Geology of the Fourth District," *Natural History of New York, Part IV* (1843), p. 459.

at an earlier stage. In any case, the striae, indicate that this slope was leeward at least part of the time, hence the subdued erosion.

In the veneer of drift we note a conspicuous number of very weathered stones. These constituents in many instances are rotten, going to pieces under a blow of the hammer; others show in cross-section a surface altered zone, one-quarter to one-half inch wide. Even the pitted quartzite bowlders are not rare.

Eastern slope of Bluff Point. On this opposite slope of the bluff a roadway leading northward from Dunning's Landing makes an exposure of highly weathered material just north of William T. Morris' cottage. This is the only section which suggests a concentration of rather uniformly altered drift constituents; neither the location nor the weathered condition of this exposure necessarily implies old drift.

About one-half mile south of Dunning's a recent stream channel reveals the contact of two distinct types of drift. The upper horizon is the familiar Wisconsin which here overlies a semi-indurated bluish till. This latter is fresh in comparison with the overlying Wisconsin which at this point is about 6 feet thick (fig. 2).

Northward along this slope a similar arrangement of drifts was noted in three places.

On these steep slopes heavy rains and spring thaws open new channels, cutting 10 feet to 15 feet in a few seasons. The Wisconsin drift is easily channeled, the other resists erosion more effectively. After a few seasons, however, the surface horizon weathers and covers the blue till formerly exposed.

As explained above, the direction of this valley is more nearly accordant with the direction of ice-movement; the older drift here was exposed, therefore, to more vigorous erosion. The portion of this old drift which has survived ice-erosion is the lower, unweathered parts. Thus the old drift is commonly fresher than the new.

The North Crosby exposure. On the opposite shore of the lake, a few rods up the hill from the North Crosby Landing, a recent stream course discloses a hard bluish till, which shows no evidence of structure, overlain by Wisconsin drift. This channel in places is 15 feet deep; the maximum showing of the basal drift is about

$4\frac{1}{2}$ feet where it forms the bed of the cut, but it is not constant, the Wisconsin sometimes forming the entire cross-section of the cut. The hardness of the blue till here is evident from the overhanging of the bowlders (fig. 3), which may be two-thirds disclosed before dropping from the face of the cut. We have not seen in this material bowlders more than a foot in diameter. The sharp angle of slope which this till maintains in comparison with that of the Wisconsin above is evidence also of the compressive force to which it has been subject.

Mixed exposures. About a mile southeast of Branchport, near the point where the old valley joins the Branchport arm of the lake, a creek trenches the recent drift, which here contains scattered masses of blue till. We noted one area at the foot of the channel wall which may be in place. The Wisconsin drift here alluded to appears to be from a lateral tongue of ice which fed into the valley, thus disturbing the older deposits.

Another area where old drift is incorporated with the new is at the end of Bluff Point (fig. 1). Here is a quantity of débris, largely local, dragged around the slope of the bluff.

Keuka Lake Outlet exposure. The most pronounced section of the bluish till may be seen along the outlet of the lake. A typical exposure is skirted by the highway and is in sight of the New York Central Railroad at Keuka Mills. Here the superjacent Wisconsin is the thinner, measuring a little less than 18 feet, while the bluish till measures nearly 30 feet. The ease with which the former weathers is demonstrated by the low angle of slope, and by the covering of vegetation; the older drift has a steep slope and no vegetation (fig. 4), and shows very slight evidence of structure.

The outlet of Keuka Lake drops 265 feet in its course of scarcely 7 miles to Seneca Lake; it consists of a rock-bound gorge alternating with amphitheater expansions, in which one or both of the rock walls are absent where the present course crosses or enters a former more mature valley. The older drift is noted particularly in these amphitheaters of the present channel. It is probable, therefore, that the Keuka basin was tributary to the Seneca basin long before the period of bluish-till glaciation.

This same relationship of drifts is noted in the erosion channels

of streams tributary to the Keuka Lake outlet. Along the lateral from the south coming in at Milo Mills, the older drift, where not very coarse, shows a tendency to lamination, the result apparently of excessive pressure. We have noted the same condition in other localities of this region.

The most persistent expression of this bluish drift is found in the Keuka outlet valley, which is transverse to the direction of ice-movement. The valley is very mature. Naturally the Wisconsin ice-sheet did less corrasive work here than in the arms of Keuka Lake.

Erosion and color. Furthermore, the line of contact of the two drifts in the exposure about Dunning's and about North Crosby gives a suggestion as to the manner and amount of the erosion. The former contact is about 65 feet above lake-level; the latter, about 90 feet. In east-west cross-section the contact line is a series of sags and swells, or anticlines and synclines, presumably parallel to the direction of ice-progress, indicating its tendency to groove or plow the subjacent surface.

The color of this old drift is strikingly blue in contrast with the adjacent yellowish Wisconsin deposits, and the color persists even in the detached masses that are seen in exposures of the recent drift. It apparently is not the result of post-Wisconsin alteration; the till has been too much protected for that, and its compactness argues against infiltering waters as the agent. The bluishness covers the bowlders and is constant in the matrix. Evidently the color antedates its erosion and burial by Wisconsin ice.

AGE OF THIS DRIFT.

The evidence presented in this paper does not warrant an opinion as to the particular pre-Wisconsin epoch of glaciation with which this drift correlates. Critical study should be given a wider area southward to the outermost moraine of the Wisconsin drift; the numerous exposures noted in the limited territory already examined suggests that other superposed sections nearer the margin may show the older drift in a weathered condition.

The freshness of the subjacent bluish till about Keuka Lake does not suggest its correlation with the highly weathered till in

New Jersey described by Salisbury. Nevertheless, this feature does not preclude identity of epochs, since the latter drift, which was never covered by a later till-sheet, has been subject to agents of disintegration during a period that has sufficed for the development of a well-advanced drainage system, the major streams having attained "levels more than 100 feet below the levels of the lowest summits on which the drift occurs."[24]

SUMMARY.

This old drift, where now exposed, with one doubtful exception, is fresh in appearance; is very compact in structure, sometimes foliated; its bowlders preserve striae; its upper surface shows erosion, presumably somewhat beyond the removal of the weathered horizon which may be the source of some of the rather rotten crystallines now mingled with the recent drift.[25]

Geological Department, Denison University, December, 1906.

[24] R. D. Salisbury, *loc cit.*, p. 759.

[25] The writer has just noted Gilbert's paper, "Bowlder-Pavement at Wilson, N. Y." (this *Journal*, vol. vi [1898], pp. 771–775). The pertinent feature of this paper is the recognition of the possibility of two till-sheets, and of the certainty of "an epoch of local till-erosion by a glacier. The epoch may be a mere episode interrupting a period of till deposition by the same glacier, or it may be a part of a stage of re-advance following a long interglacial period" (p. 774).

AN ESKER GROUP SOUTH OF DAYTON, OHIO.[1]

EARL R. SCHEFFEL.

Contents.

Introduction. This paper has for its object the discussion of an esker group[2] south of Dayton, Ohio,[3] which group constitutes a

[1] Reprinted from *The Ohio Naturalist*, vol. viii, January, 1908. Given before the Ohio Academy of Science, November, 30, 1907, at Oxford, O., representing work performed under the direction of Prof. Frank Carney as partial requirement for the Master's Degree.

[2] F. G. Clapp, *Jour. of Geol.*, vol. xii (1904), pp. 203–210.

[3] The writer's attention was first called to the group the past year under the name "Morainic Ridges," by Prof. W. B. Werthner, of Steele High School, located in the city mentioned. Professor Werthner stated that Professor August F. Foerste of the same school and himself had spent some time together in the study of this region, but that the field was still clear for investigation and publication. Professor Foerste later made practically the same statement. The writer is

part of the first or outer moraine of the Miami Lobe of the Late Wisconsin ice where it forms the east bluff of the Great Miami River south of Dayton.[4]

General Discussion of Eskers. Much question and dispute has arisen in the past concerning the terminology[5] for certain ridge-like products of glaciation, but the designation "esker" is generally applied by American geologists to lines of débris presumably aggraded by streams between walls of ice. Though the theory of deposition in sub-glacial tunnels[6] holds the greatest credence today, the en-glacial and super-glacial or various combinations of the three theories have been offered as plausible explanations in specific instance.[7] For convenience this article assumes in the beginning that the Dayton ridges are eskers, and that they were formed in sub-glacial tunnels.

Preliminary Description of Region (fig. 1). The northern end is known locally as "The Bluffs." These trend east-northeast to west-southwest about half a mile, presenting an abrupt slope considerably over one hundred feet high toward the valley of Dayton to the north. The Miami canal runs along the slope not far from its bottom, and below this at the base of the Bluffs flows the Great Miami River. The topography of this and also of the western half of the area presents a beautiful study in kames; mounds and basins[8] are abundant. The mounds or knolls frequently show a tendency toward alignment, producing ridges. The eskers indicated on the map constitute the eastern boundary

indebted to both of these gentlemen for their courtesy. He also wishes to thank his instructor Professor Carney, for going over the field with him and taking the several excellent photographs illustrating this article.

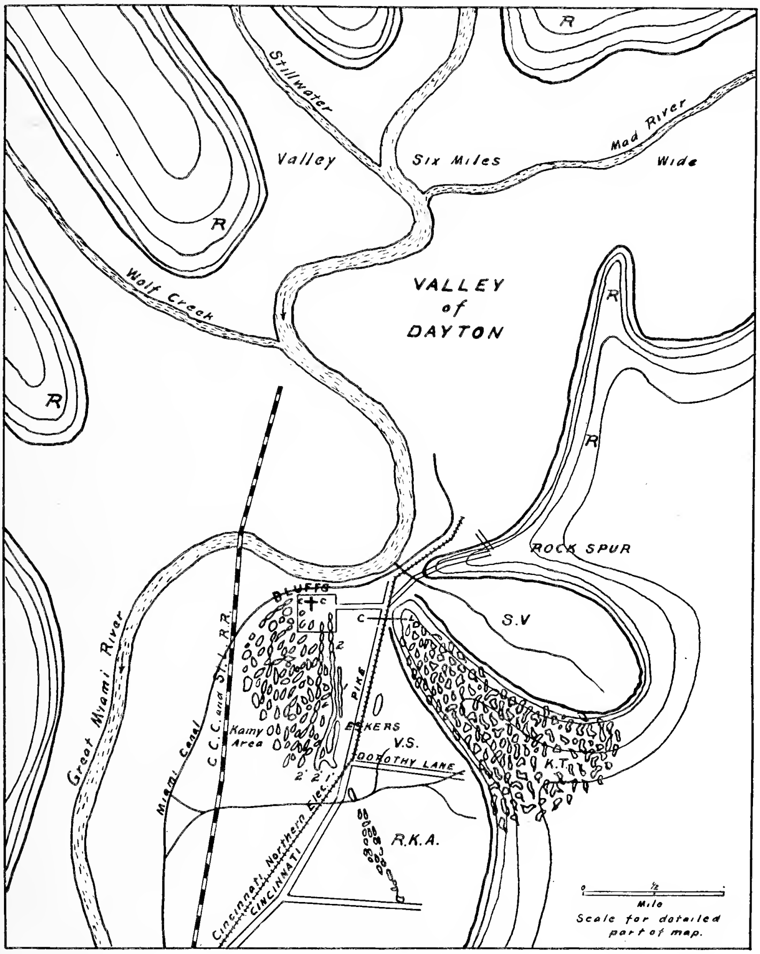
[4] F. Leverett, *Monograph XLI, U. S. Geol. Surv.* (1902), p. 355. T. C. Chamberlin, *3d Annual Report, U. S. Geol. Surv.* (1881–1882), p. 334.

[5] G. F. Wright, *The Ice Age in North America* (1891), p. 296; G. H. Stone, *Monograph XXXIV*, U. S. Geol. Surv. (1899), pp. 35, 359. W. C. Morse, *The Ohio Naturalist*, vol. vii, (1907), pp. 63–65.

[6] Chamberlin and Salisbury, *Geology*; (1906), vol. iii, pp. 373–377.

[7] W. M. Davis, *Proc. Bos. Soc. Nat. Hist.*, vol. xxv (1892), pp. 477–499; J. B. Woodworth, *Proc. Bos. Soc. Nat. Hist.*, vol. xxvi (1894), pp. 197–220; O. H. Hershey, *Am. Geol.*, vol. xix (1897), pp. 197–209, 237–253; W. O. Crosby, *Am. Geol.*, vol. xxx (1902), pp. 1–39.

[8] T. C. Chamberlin, *loc. cit.*, p. 334.



GREAT MIAMI VALLEY
FIG. 1.

This figure shows in the lower part a map of the esker and kame region. The topographic features are drawn purely diagrammatic, being intended only to give a general view of the relationship of the valleys, esker and kame area to the valley walls.

Representations of Initial Letters: *R*, Rock (outcrops); *S. V.*, Small Valley; *V. S*, Valley Segment; *K. T.*, Kamy Topography; *R. K. A.*, Ridged Kame Area; 1, 2, Eskers nos. 1, 2; 1′, 2′,—Knoll Endings of Eskers; *C. C.*, Calvary Cemetery; *C. L.* Southern Corporation Line of City of Dayton.

of this kame area. They overlie their base like railway embankments crossing uneven topography.[9] From the region of the Bluffs they proceed southward about a mile ending bluntly on the Miami Valley. The crest-lines are sinuous in both vertical and horizontal directions, though the general course is in almost a straight line. The esker form is at times modified by knolls, rarely by distinct gaps. The crests are narrow and the sloping sides steep, apparently taking the angle of repose normal to the débris of which they are composed. Both the eskers and the kamy topography westward rest upon a base rising above the valley of the Miami. To the southeast, across the roadway from the southern ends of the eskers the kamy topography continues for about a mile. This topography shows a curious branching and anastomosing of ridges. Though at present suggestive of kames it is quite possible that it represents modified glacial phenomena of other than kame origin. A more elaborate study of this will be made in a future paper.

Bearing on archæology. There has been a tendency in the past to explain formations of the esker type as the work of Indians or Mound Builders,[10] an error not without justification. Evidence of design in the Dayton ridges is patent to the uninitiated. They suggest an immense fortification composed of lines of earthworks; the knolls serving as lookout and signal stations, gaps for ingress and egress, and short connecting embankments as roadways from ridge to ridge. Several references are made in local histories[11] to the work of Mound Builders found in what is now Calvary Cemetery (*C. C.*, fig. 1). Of these the following quotation is the most comprehensive: "South of Dayton on a hill one hundred and sixty feet high is a fort enclosing twenty-four acres. The gateway on the south is covered in the interior by a ditch twenty feet wide and seven hundred feet long. On the northern line of embankment is a small mound from the top of which a full view of the country for a long distance up and down the river may be

[9] Chamberlin and Salisbury, *loc. cit.*, p. 375.
[10] G. H. Stone, *loc. cit.*, p. 35.
[11] *History of Montgomery County*, Ohio (1882), p. 216.

obtained."[12] Other isolated portions are explained similarly by residents.

Such explanations are to be doubted as few if any more than the number of Indian relics normal to this section of Ohio are found. Even admitting the archæologic suppositions, the accredited Indian work constitutes so little of the region studied, with but trifling interference to the general plan, that it may be disregarded. That no large portion can be of human construction is apparent not alone from the size of the formation, but from the evidence of assorted material in numerous cuts.

Topographic relations. Eskers differ in their relations to the topography of the area on which they rest, but according to Chamberlin and Salisbury they were probably most frequently made by streams flowing about "parallel to the direction of the ice movement."[13] The same writers also suppose the most favorable position for their formation to be "near the edge of the ice during the time of its maximum extension or retreat."[14]

It is possible that the topography of the Dayton area offers the best explanation, on a sub-glacial hypothesis, for the origin of these local eskers. Dayton lies in a large valley (fig. 1) formed by the junction of the Stillwater and Mad Rivers and Wolf Creek with the Great Miami River. The enclosing rock-bearing hills rise about 200 feet above the flood plain. The basin is filled with a varying depth of débris exceeding in places 200 feet.[15] The maximum width of the valley is about six miles. To the southward beyond the junctions the valley narrows to about one-third its greatest width. This narrowing is produced principally from the eastern side by a rock spur (fig. 1), south of which the valley again widens but not to its former size. The last rock outcrop on this spur was found on its top and several hundred yards from the end. The Bluffs extend west-southwest from this spur, the two prominences being separated by a gap which permits the egress

[12] Quotation in "History of Dayton" (1889), p. 10, from J. P. McLean's work, *The Mound Builders*.

[13] *Loc. cit.*, p. 376.

[14] *Ibid.*, p. 374.

[15] F. Leverett, *loc. cit.*, p. 361.

of drainage from a small valley (*S. V.*, fig. 1) connected with the spur. The eskers and kame area spreading southward from the Bluffs cut off a small segment of the Great Miami Valley (*V. S.*, fig. 1) lying south of the spur.

Theories of origin. In diagrammatic view (fig. 1) the valley of Dayton appears as an oblong basin with wide gaps for the entrance of the Miami River and tributaries, and one for the departure of the combined drainage. This great basin may have exerted an important influence on the waning glacial ice in controlling its movement in this area, and also in concentrating drainage that became sub-glacial.[16] That this basin and its tributaries do represent glacial drainage lines[17] is proved by the great depth and character of the débris filling. The over-riding ice would drop into the Dayton valley as in a pocket. This in the stagnant ice stages would accentuate its immobility thereby conducing to esker-forming conditions. The concentrated drainage would seek the point of easiest egress which would probably be somewhere in the gap to the south. While under great head, as doubtless the drainage would be at times of most active ice-melting, topography might to some extent be disregarded. This could explain the appearance of the ridges on the eastern side of the valley gap (possibly even superimposed over a continuation of the rock spur) rather than in the center.[18]

The close association of the eskers with kame deposits suggests that the latter were formed during the retreat of the ice after the eskers had been built in sub-glacial stream tunnels. This kame area doubtless spread originally further across the valley but has in part been removed by the meanderings of the Miami River. The abrupt face presented to the north by the Bluffs may also have the same explanation; it has already been noted that this river flows at the present time along their base. If this explanation is correct, the kame and esker topography may formerly have extended an indefinite distance northward into the Dayton valley.

[16] I. C. Russell, *Jour. of Geol.*, vol. iii (1895), p. 827. O. H. Hershey, *loc. cit.*, p. 240.

[17] F. Leverett, *loc. cit.*, Pl. II.

[18] Chamberlin and Salisbury, *loc. cit.*, p. 375.

Detailed Description of Eskers. It is unsafe to number these ridges as marking separate and distinct lines of drainage, but for convenience this method will be adopted. The easternmost will be designated no. 1 and the next, west no. 2. Other lines may exist buried beneath and masked by the kame deposits.

No. 1 (figs. 1, 2.) This may branch from no. 2. As an independent ridge it proceeds from its head (about a quarter of a mile below Calvary Cemetery) southward and almost parallel with the Cincinnati Pike to a point almost opposite Dorothy Lane (fig. 1)

FIG 2. View looking north on esker no. 1.

where it ends in a cut. The upper end of this esker though distinctly ridged is not as typically esker-like as the lower end. Intersections between no. 1 and no. 2 occur near their southern terminals. These intersections at one point form a "Y," the base of which starts from no. 1, the branches leading to no. 2. At all the intersections, four in number, the ridges rise, forming knoll-like prominences. Small bowlders about the size of cobbles are abundant on the surface. These are largely of local limestone of the same formation (Cincinnati) as that seen in the rock spur before mentioned. The exposed cut at the road shows principally

coarse gravel mingled with sand. Some of this gravel has been cemented together into a form of conglomerate by the action of carbonated water.[19] Several feet of till containing a large percentage of small bowlders overlies the gravel at this point. This exposed section at the time of the writer's first visit revealed the anticlinal stratification frequently mentioned in offering sub-glacial theories of origin. This may possibly be explained, however, by slumping of the material after the withdrawal of the ice. This cut has been extensively used by the Cincinnati Northern Electric, which runs alongside, in securing ballast for its new roadway.

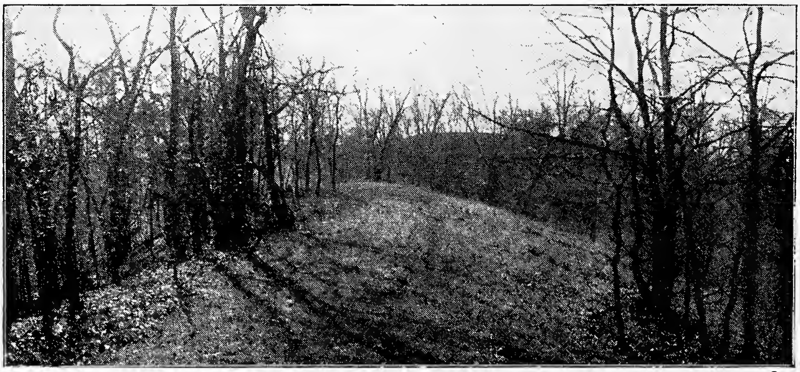


FIG. 3. (*F. Carney*). View looking north on esker no. 2. A sharp turn and steep rise shows in background.

No. 2 (figs. 1, 3, 4.) This starts just within Calvary Cemetery. A short longitudinal cut has been made on the west side of this end, furnishing the gravel supply for the cemetery. From an abrupt rise it proceeds southward, coming alongside of no. 1, and following almost parallel. To the south it branches and ends bluntly on the Miami Valley in two prominent knolls aligned with the cut of no. 1 (figs. 1, 6). Water is imponded at several points between no. 1 and no. 2. This ridge is separated the greater part of its length from the kamy area to the west by a distinct and deep trough.

[19] E. Orton, *Geol. Surv.*, of O. (1869), p. 146.

Kamy area to the west of eskers (figs. 1, 5). The kames here show a tendency toward alignment in short ridges. Sometimes they appear to radiate from a common center. Artificial cuts facing the valley show prevailingly fine material indicating by the stratification a very active play of waters.

Studies.

Proximity of eskers. The distance between the two eskers is always slight. The surface outline of this distance is usually similar to a parabola shaped trough of such a size that if one of the adjoining ridges were inverted it would approximately fit the trough. The drainage from the troughs is principally through the soil.

Height of eskers. The variation in altitude of the crest-lines and of the troughs gives varying heights at different points. No. 2 by aneroid measurement varies from 35 – to 95 + feet in height. No. 1, if measured, doubtless would give similar results.

Reticulation. The two eskers show several connecting branches. This implies a union between the lines of drainage some time during their existence. These connecting branches are so depressed in parts that tracing is difficult. Such a condition would be natural as the cross drainage would normally be so sluggish that the tunnel carrying it would probably never attain a large size. It is a question whether the two eskers represent branches from one line of drainage or are entirely independent. They may even represent a shifting of drainage lines. The lower end of no. 1 suggests by its position (fig. 1) that it may be a branch from no. 2, rather than a continuation from the head end of no. 1, as we have described it.

Knolls. Hummocks are frequent. Generally they mark the southern termini and ridge junctions. At its head end no. 2 is composed of a series of four joined together. Many theories[20] are given for the origin of such swellings. In connection with knolls other modifications of the esker type may be noted. Several buttress-like deposits were found lying against the bases of the

[20] J. B. Woodworth, *loc. cit.*, pp. 202, 203.

eskers; sometimes also a fan-like spreading of débris from a similar position was observed. These irregularities probably mark the entrance to the major line of small tributary streams, or as an alternative, the opposite condition, leakage from the major lines. The knolls at the head of no. 2 are more suggestive of tributaries than of kames.

The knoll-endings (figs. 1, 6) on the Miami Valley suggest by their alignment that they have been cut off at this point by the Miami River. Though this stream here turns to the westward, the even floor of the valley is evidence that it formerly turned eastward. The fanning of the knoll-endings into the valley where

Fig. 4. (*F. Carney*). Camera reversed from fig. 3, and view taken looking south on same esker.

they meet in an even slope is doubtless the result of slumping. Davis[21] gives a clear exposition of conditions when bodies of water are dammed by the ice-front, with the consequent phenomena of sand plains built up by esker streams. The Dayton area, however, shows no evidence of favorable conditions for the holding of ice-front waters, drainage having a perfectly free course toward the south. Streams emerging from the ice would spread out and quickly drain away. In this particular area such an outwash plain if formed would have been destroyed long ago by the erratic wanderings of the Miami.

[21] W. M. Davis, *Bull. Geol. Soc. Am.*, vol. i (1890), pp. 195–203.

Altitude of these deposits. The elevation of the area above the valley is partly due to the base upon which it rests. This is shown particularly in the kame region, the inside slopes of which are much shorter than the slopes facing the valley, a condition explainable by slumping within the area and erosion around it by the Miami as before stated.

In this connection it may be suggested that possibly gradation has greatly modified the original eskers. At the time of ice-withdrawal these forms, particularly if sub-glacial in genesis, must have been left with little or no vegetative protection. It cannot be determined how long a time was required before plant life secured a

FIG. 5 (*F. Carney*). Kame area immediately west of esker no. 2. Camera facing north. Barn rests on a long ridge of kames.

good foothold, but it is reasonable to suppose that the interval was sufficient to permit considerable weathering even on such narrow forms as eskers. With the eskers in question is it not probable that after the constituting material had assumed its natural angle of repose they may have been considerably lowered by gradational processes? Such processes would also reduce the effect of height by partially filling the trough.

Composition of eskers. A layer of bowldery till spreads over the group. This varies in thickness, sometimes being five or six feet deep. Such a deposit, of course, supports the theory of subglacial origin, representing as it does the melting of a body of débris-laden ice above. The gravel beneath this till in the eskers is composed of a large percentage of Ohio limestone intermingled

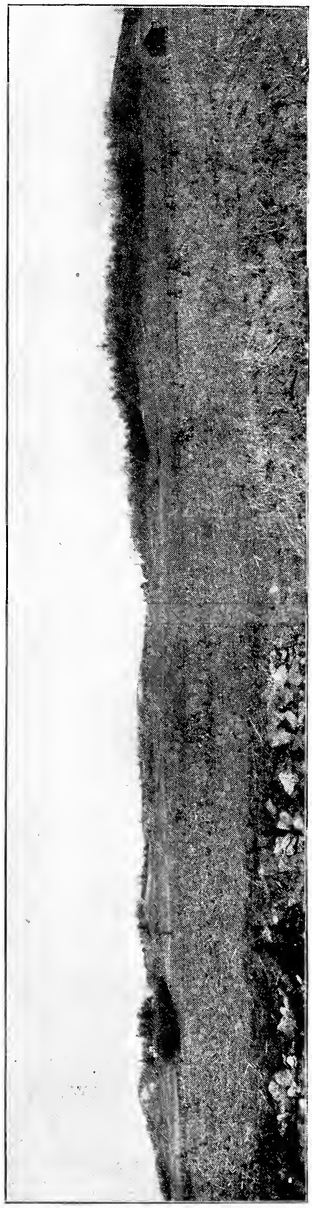


FIG. 6 (*F. Carney*). View looking north from Miami Valley, showing southern termini of eskers. Knoll to right belongs to esker no. 1. Two knolls next west apparently belong to esker no. 2. Westernmost knoll is a part of the kame area.

with foreign rock. Though mixed with sand it is practically free from clayey material. Cobbles of flat angular limestone are abundant on the surface. At times these cobbles intermingled with foreign bowlders of similar size literally pave the surface, a result possibly of concentration through the removal of fine material by washing. Big granite bowlders are rare.

Rock weathering. The surface bowlders show varying degrees of weathering. The limestone, not being very resistant to water action, particularly shows age. Granites sometimes appear fresh, at other times are decidedly pitted. If this irregularity is not due to their chemical composition, the inference would be that bowlders representing several different glacial periods have been mingled. In a stream-cut south of the eskers many greenstones appear. These are described by Chamberlin and Salisbury[22] as particularly abundant in sub-Aftonian drift. It may be that in these conditions evidence may be found that this area represents pre-Wisconsin glaciation and later reworking during the Wisconsin period. Such a theory would not necessarily oppose anything that has already been conjectured with regard to the history of the region.

Crest-lines. While the crest-lines are sometimes quite hummocky, the typical esker form is found in all its beauty. Straight, even-sloped sections several rods in length may be found, but the course usually is serpentine, the crest-line waving up and down and from one side to the other of a straight line. Several gaps occur, some perhaps artificial; others may be due to constrictions in the ice tunnel or various local modifying conditions. Though the general course of these eskers is straighter than in the usual type, this offers nothing inconsistent with the sub-glacial theory of origin; in fact it seems reasonable to suppose that confined streams of sufficient size to build up immense ridges of coarse material would naturally hold to a comparatively straight course.

Economic Importance.

These ridges have great economic value. The supply of gravel and sand is practically inexhaustible. The C. C. C. & St. L.

[22] *Loc. cit.*, p. 384.

steam R. R., and the Cincinnati Northern Electric run conveniently near and have made extensive cuts in securing ballast. The position of the ridges overlying the valley reduces the expense of cutting to a minimum. Tracks are run alongside and big steam scoops gather up the gravel and throw it into cars. In addition to that used by the railroads many loads are taken away in wagons. Formerly considerable sand and gravel was taken from the Bluffs by boats plying on the canal; this method of transportation is no longer operative, partly because of the decreased depth of this waterway. The group occupies something less than a square mile of surface. But little of this acreage is devoted to farming, most of it serving for pasture. There are several very desirable locations for summer homes and also opportunities for parking.

Area to the East.

The easternmost esker and the ridged relief starting on the opposite side of the roadway at its southern end block off a portion of the valley apparently belonging at one time to the Great Miami, though the level of this valley is considerably higher than the present flood plain of the Miami Valley.

Conclusion and Summary.

Eskers of Ohio have not been studied so exhaustively as those of other parts of the country, particularly of New England. Leverett, however, mentions eleven in this state, according to the tabulation by Morse,[23] in his article on the "Columbus Esker."

In describing this area and in drawing inferences the writer has endeavored to be exact and not dogmatic. Some slight errors may have been made in data; theories in any case are uncertain. It may not be possible to work out with assurance the history of the group. So many factors may have operated together or against each other that the result would appear to be without "rhyme or reason" and too complicated for unraveling. From the present day evidence, however, the following conclusions are reached with some confidence:

[23] *Loc. cit.*, p. 66.

1. These eskers conform in details to the type generally conceded to be of sub-glacial origin.
2. Their location was largely dependent on topography, lying as they do in a position favoring active sub-glacial drainage.
3. The heavy stratified glacial deposits other than eskers also indicate an activity of drainage beneath the ice or from its front.
4. The varying texture of the bowlders suggests a reworking of old glacial débris by the last ice-sheet.
5. The inexhaustible supply of gravel and sand offered, together with convenient location and easy access, give the area considerable economic value.

Geological Department, Denison University, November, 1907.

WAVE-CUT TERRACES IN KEUKA VALLEY, OLDER THAN THE RECESSION STAGE OF WISCONSIN ICE.[1]

FRANK CARNEY.

The tracing of the shore phenomena of the high-level lakes which characterized the recession of the Wisconsin ice sheet in New York State, particularly by Fairchild,[2] is one of the most interesting and fascinating of the contributions to glacial geology. Other geologists have performed similar tasks here and elsewhere in the basin of the Great Lakes.[3] The post-Wisconsin deformation or tilting of these ancient beaches has attracted the attention of many investigators,[4] Dr. G. K. Gilbert having given the subject special study.[5]

So far as the writer is aware, however, no study has been given to the evidence of static water bodies that presumably existed in this region in front of the advancing Wisconsin ice, nor to those which on *a priori* grounds probably existed in connection with both the retreat and advance of preceding ice-sheets. There is very

[1] Reprinted from *The American Journal of Science*, vol. xxiii, May, 1907.

[2] H. L. Fairchild, *The Amer. Journ. of Science.*, vol. vii, 1899, "Glacial Lakes Newberry, Warren and Dana in Central New York"; *Bulletin Geological Soc. Am.*, vol. x, pp. 27–68, 1899; New York State Museum, *20th Rep. of the State Geologist*, 1901, "The Iroquois Shore Line," pp. r106–r112.

[3] G. K. Gilbert, *Geol. Survey of Ohio, Rep. of Progress*, 1870, pp. 488–90; same, vol. i, 1873, pp. 549–555, 559–560, 569–570; *Sixth Rep. of the Niagara Commission*, pp. 61–84, 1890; T. C. Chamberlin, *Geol. Survey of Wisconsin*, vol. ii, pp. 219–229, 1877; J. W. Spencer, *Bull. Geol. Soc. Am.*, vol. i, pp. 70–86, 1899; same, vol. ii, pp. 465–476, 1891; same, vol. iii, pp. 488–492, 1892; A. C. Lawson, Geological and Natural History Surv. of Minnesota, *20th Annual Rep.*, pp. 230–289, 1891; F. B. Taylor, *American Geologist*, vol. xviii, pp. 108–120, 1896; *Bull. Geol. Soc. Am.*, vol. viii, pp. 31–58, 1897; same, vol. ix, pp. 59–84, 1898; Frank Leverett, *Monograph XLI*, U. S. Geol. Survey, pp. 371–383, 1902.

[4] F. B. Taylor, *American Geologist*, vol. xiii, pp. 316–327, pp. 371–383, 1894; J. W. Spencer, *The Amer. Journ. of Science*, xli, pp. 201–211, 1891; G. K. Gilbert, *Smithsonian Report*, 1890, pp. 236–244. (For more extended bibliographies under footnotes, see R. S. Tarr, *Physical Geog. of New York State*, pp. 240–265, 1902.)

[5] G. K. Gilbert, *18th Ann. Rep.*, U. S. Geol. Surv., 1898, pp. 595–647.

slight reason for thinking that the topographic relations of the lowland area north from the Niagara escarpment and the Allegheny plateau section of central and western New York have changed much since the beginning of the Pleistocene period. Such being the case, then the duration of the pre-Wisconsin ice-dammed lakes determined the emphasis of the shore phenomena attained. Existing evidence of these old shore lines must, in most cases, stand for sharp initial development, as the vigorous Wisconsin ice with its great amount of débris tended to obliterate such minor details of pre-Wisconsin topography.

LANDWARPING.

Geologists early recognized the proof of instability in the altitude of land areas. It was further recognized that the range of vertical variation is not constant for any great horizontal distance. The Great Lakes area has already been shown to be rich in the evidence of such deformations.

That the oscillations in the altitude of northeastern North America incident to the late Wisconsin[6] stage and the succeeding stage of the Hochelagan formation[7] represent the entire range of such variations during the Pleistocene period is not necessarily true. With marine fossils in clays and sandy clays 540 to 560 feet above present sea-level,[8] and stream-cut channels at least 630 feet below present sea-level,[9] we have an interval of altitude that probably dates from the earliest ice-epoch or even earlier. The surprising erosion in the Seneca Lake Valley at Watkins, N. Y., reported by Tarr, has increased significance when connected with the deductions made by Fairchild concerning the ancient valley that leads into the Sodus Bay arm of Lake Ontario.[10] These deeply buried valleys far inland, and mature but riverless valleys seaward, suggest landwarping of like nature, but of far greater antiquity than that proved in the investigations of the Iroquois beach.

[6] DeGeer, *Proc. Boston Soc. Nat. Hist.*, vol. xxv, pp. 454–477, 1892.

[7] J. B. Woodworth, New York State Museum, *Bulletin 84*, p. 204, 1905.

[8] J. B. Woodworth, *ibid.*, pp. 215–216, 1905; *ibid.*, *Bulletin 83*, pp. 46–50, 1905.

[9] R. S. Tarr, *American Geologist*, vol. xxxiii, p. 277, 1904. Professor Tarr reports a well boring at Watkins, N. Y., 1080 feet deep without reaching rock.

[10] *Bulletin Geol. Soc. Am.*, vol. xvi, pp. 70–71 1905.

THE ALTERATION OF SHORE LINES BY LATER ICE-INVASIONS.

Partial or complete effacement of the constructional and destructional products of wave and current work in these pre-Wisconsin ice-dammed lakes would be expected. The sweep of an ice-invasion, followed by the destructional work of the slowly falling bodies of water marking the period of ice-recession; would necessarily modify, remove or cover such features as terraces in unconsolidated materials, as bars, spits, cusps, etc.; whereas the cliffs and terraces in rock would be much less altered.

The potency of ice as a factor in erosion does not make an identical appeal to all observers; this is when the sculpturing of bedrock is under consideration. So it is possible that all will consent to the general, though not complete, removal by erosion of the constructional products of lake waves and currents. As a matter of field study, however, it may as well be granted that these constructional forms have been entirely obliterated; the differentiation of a bar, or delta belonging to some pre-Wisconsin lake, from the water-laid portions of glacial drift would require an environment unusually free of other deposits. But we must grant that cliffs and terraces formed in rock would be less affected by glacial erosion.

The extent to which these cliffs might be modified by erosion would depend upon their topographic relations. Ice abrasion is more effective on the slopes opposed to ice motion; it is more effective also along the lower contours of the walls of the valleys trending with the direction of the moving ice. Hence in a series of terraces along a valley wall, the lowest one would be the most modified by glacier ice.

The beach structures of these former lakes have suffered further from wave work of more recent water bodies, especially of the high-level lakes. The degree of effacement through this agency depends upon the coincidence of the surface-planes of the two bodies of water, or upon their approximation to coincidence; if these planes intersected at a very slight angle, the vertical range of beach agents would at least partially overlap for a considerable horizontal distance; if the planes were actually coincident, then

the extent of the defacement would depend largely upon the relative duration of the two bodies of water.

Probably the most effective agency in the obliteration of these shore structures is the deposit of drift made by an ice sheet. Within the belts of thickened drift the burial must be quite complete, the chances of survival being greater with the higher beaches. But at all levels the mantle of ground moraine would in any event partially cover the weaker expressions of wave and current work. And even the pronounced cliffs and terraces might be covered in places.

FIG. 1. View just north of Dunning's Landing. Terraces No. 2 and No. 3 show here. The steepened slope nearest the lake may represent the lowest terrace altered by ice-erosion.

Furthermore, normal subaerial weathering has tended to render less obvious such remnants of these old beaches as have survived the factors above described; the least changed would be the forms cut in the more resistant rocks.

FORMS WHICH SIMULATE WAVE-CUT TERRACES.

1. Variation in the texture of rocks is manifest in differential weathering;[11] sharp slopes simulating cliffs may be thus produced.

[11] T. L. Watson, N. Y. State Mus., *51st Ann. Rep.*, vol. i, p. 176, 1897.

The resemblance, however, leads to confusion only when the plane of the lake surface coincides with, or is parallel to and vertically within a few feet of, the hard layer or horizon of rock which marks the bench; such a ledge, in the absence of a terrace or other evidence of a beach, cannot be defined finally as a wave-cut cliff. The attitude of a bench resulting from weathering, in reference to the horizon, depends upon the dip and strike of the hard layers; because of this fact, it is not difficult to distinguish the wave-cut cliff, except when the bench is discontinuous, showing only in short segments, a condition not unusual in the coarse sandstone horizons because of the horizontal variations in texture.

2. Streams held against a slope, or against a rock salient, by ice, often form a bench somewhat simulating a wave-cut terrace and cliff.[12] Such benches have been investigated by Fairchild,[13] who shows how the banks of glacial drainage streams differ from the wave-cut cliff.[14] The latter is not so localized as the former, nor in general, so marked in development.

Considerable effort was devoted to explaining the terraces in question as the result of differential weathering. The other explanation, ice-stream work, was easily eliminated. The third interpretation, discussed in this paper, suggested itself after it became apparent that neither of the other two was pertinent.

STRATIGRAPHY OF BLUFF POINT.[15]

The succession of formations as given in Bulletin 101 of the N. Y. State Museum (which appeared after the close of the field season during which this study of wave-cut terraces was prosecuted), a report prepared by Luther, has been used by the writer in checking up his field notes on the stratigraphy of the area involved; these notes concern only the lithological aspect of the formations exposed, and since the slopes of Bluff Point are rather sharp, the rock section is almost complete.

[12] G. K. Gilbert, *Bulletin Geol. Soc. Am.*, vol. viii, p. 285, 1897.
[13] N. Y. State Mus., *22d Rep. of State Geologist*, pp. r23–r30, 1902.
[14] *Ibid.*, *21st Rep. of State Geologist*, pp. r33–r35, 1901.
[15] The Penn Yan Quadrangle will serve as an index map for this region.

The compact sandstone layer, referred to by Clarke and Luther, about 125 feet above the base of the Cashaqua as revealed in the Naples region,[16] appears near Keuka Park and persists southward about one and one-half miles; much of this distance it forms a prominent bench.

The next formation that might include beds for registering differential weathering effects is the Hatch shales and flags, which attain a thickness of about 300 feet.[17] Along the slopes of Bluff

FIG. 2. View of west shore Penn Yan branch about two miles north of Dunning's Landing. Shows terrace No. 2, and what is apparently the lowest terrace altered probably by ice-erosion.

Point the sandy layers of this formation, though irregular in both horizontal and vertical distribution, are conspicuous. The greatest thickness of shale noted in any exposure is about 12 feet; the base of this horizon is 261 feet (corrected aneroid reading) above lake-level; it could not be demonstrated that this horizon of shale had much horizontal extension. Likewise the arenaceous layers, the heaviest noted being under 2 feet, do not persist horizontally.

Next in rising section is the Grimes sandstone, estimated by

[16] N. Y. State Mus., *Bulletin 63*, p. 31, 1904.
[17] D. D. Luther, N. Y. State Mus., *Bulletin 101*, p. 47, 1906.

Luther to be 75 feet thick.[18] This formation is above the terraces in question, so its characteristics do not concern us.

It appears, therefore, that there is no factor in the stratigraphy of this area to account for the marked benches. No conditions could be more favorable for registering the differential effects of weathering than the topography formed by this peninsula of rock dividing the two arms of Keuka Lake.

CLIFFS IN KEUKA VALLEY.

The succession of post-Wisconsin high level lakes that formerly occupied this region has been worked out by Fairchild. He designates the overflow channels of the principal stages, correlates the deltas, and points out some localities of wave-work.[19]

The terraces and cliffs which occasion the present paper have been studied in some detail along the flanks of Bluff Point. Terraces apparently of the same age have been noted elsewhere on the walls of Keuka valley, but have not been critically examined.

The most obvious reason for not associating these cliffs and terraces with the work already done is the fact that they are overlain and intersected by lines of Wisconsin drift. This drift is in place, and so far as observed, shows no evidence of wave-work along the planes of the terraces in question; furthermore, the drift is particularly well developed where it crosses the terraces (fig. 3).

These terraces, designated by numerals, are described in regular order ascending from present lake-level.

No. 1. This is not a clear case. For some distance southward from Keuka Park is a bench and terrace; the relation here is conspicuous enough, but the cliff consists of the hard beds in the Cashaqua already alluded to; it stands about 70 feet above the lake, but descends southward. There is, however, a persistent suggestion of a bench southward to vicinity of Dunning's, not a continuous shoulder, but a recurrence of over-steepened short slopes forming a plane that ultimately dips beneath the water.

[18] *Ibid.*, p. 49, 1906.

[19] *The Amer. Journ. of Science*, vol. vii, pp. 255–256, 258, 1899; *Bulletin Geol. Soc. Am.*, vol. x, pp. 4–41, 1899.

That the intervals of these benches are connected genetically with the more continuous shoulder and terrace to the north is not established. Furthermore, the discontinuity southward of the better developed cliff is possibly due to the vigorous ice-erosion that altered the lower horizons of the walls of the longitudinal valleys.

No. 2. This bench and terrace first shows about two and one-half miles north of Dunning's Landing. It is remarkably continuous (figs. 1, 2), and generally sharp in development. At one

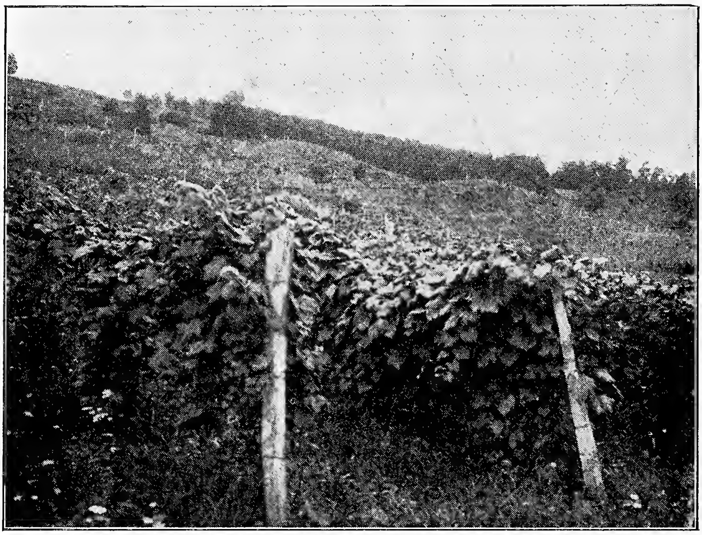


FIG 3. Shows a lateral moraine which crosses the middle and highest terraces, and descends to lake level south of Ogoyago.

locality towards the north, where the eastern slope of Bluff Point blends into the northern slope, the twelve foot horizon of shale, mentioned in preceding section, was noted; here the shale is nearer the top of the bench; not much importance, however, is attached to this vertical position, further than to note that it could have no genetic association with the bench. The original relationship of terrace and cliff, so far as analysis of a particular cross-section is concerned, has been given much indefiniteness by the agents of degradation; whereas this relationship is still conspicuous when viewed from a distance.

As a distinct feature of the slope, this terrace disappears where the valley wall becomes very steep towards the southern end of the Bluff. The till at the end of the Bluff is made up largely of local material; there is other evidence also of vigorous corrasive work by the glacier on the slopes near the end of Bluff Point.

No. 3. On the supposition that these terraces represent a body of water that fell successively to the levels indicated, terrace No. 3 is the oldest; but the difference in the degree of weathering attained, or in the sharpness of profile, is not noticeable. This terrace apparently does not extend as far north as no. 2; there is, however, some obscurity in this direction due to its disappearing beneath a wide band of drift. Furthermore its identification is not obvious quite as far south as Ogoyago; so terrace No. 3, in linear extent, falls short of the next lower terrace.

TIME PERIODS OF THESE CLIFFS.

The measure of post-Pleistocene time has been attempted through several lines of observations: The years involved in the carving of the Niagara and other gorges, in the construction of flood plains, etc., have been estimated relatively to units which do not admit of very accurate determination because of the interdependence of degradational activities, a variation in any one of which would give the units quite different values. Time-ratios of the continuity of certain phases of geological activities are less objectionable.

From a study of the extent to which erosion has effected the several sheets of till, certain ratios have been deduced using the erosion period of the Late Wisconsin drift at a time-datum. The approximate value of this ratio, which may be subject to alteration through the acquirement of new facts, for the Early Wisconsin is 2; for the Iowan, 4; for the Illinoian, 8; for the Kansan, 16.[20] The drift of the Mississippi Basin has furnished most of the data concerning these epochs of glaciation. It has already been estab-

[20] Chamberlin and Salisbury, *Geology*, vol. iii, pp. 413–421, 1906. Here is found a succinct presentation of the data on which are based the relative time-periods of the stages of the Glacial Period.

lished that the glacial period in the East was also composite;[21] but a parallelism of epochs has not been worked out.

For the purposes of the present paper, however, it is assumed that the Lake Region of New York had been glaciated previous to the Late Wisconsin stage, an hypothesis already used by others;[22] and that the interval or intervals of deglaciation were not shorter than the time-ratios held tentatively for the Mississippian area.

Illustrations of the wave-cutting work done by some of the Finger Lakes since they were lowered to their present levels are common in geological literature.[23] One who is acquainted with Seneca Lake will recall the high cliff on the east shore near Watkins, at the head of the lake; and other localities along this lake show quite as marked wave-work. Along the present shore of Keuka Lake the cliffs are not so well developed, but benches of 20 feet or more are not uncommon.

If lakes occupied these longitudinal valleys during the interims of glaciation, cliff-cutting could have proceeded to such an extent as to make survival in certain localities, at least, probable. Even the shortest inter-glacial period, on the assumption that the stages of the ice age represent oscillations of the ice from continuously ice-covered dispersion areas, was much longer than post-Wisconsin time, which has sufficed for defining exact shore lines. But terrace No. 3 has an altitude that is impossible if the body of water with which it is genetically connected discharged over any of the present cols leading into the Susquehanna area; all of the overflow channels reported for the Keuka valley are too low. It may be said, however, that many of these interlocking valleys of the St. Lawrence-Susquehanna basins, through which the waters of the high-level ice-front lakes spilled, have local characteristics which are not normal to the regular development of valleys; the conditions here alluded to will be discussed in a separate paper,

[21] R. D. Salisbury, Geol. Surv. of New Jersey, *Ann. Rep. for 1893*, pp. 73, etc.; J. B. Woodworth, N. Y. State Mus., *Bulletin 48*, pp. 618–670, 1901; F. Carney, *Journal Geology*, vol. xv (pp. 571–585), 1907.

[22] R. S. Tarr, *American Geologist*, vol. xxxiii, p. 282, 284, 1904; H. L. Fairchild, *Bulletin Geol. Soc. Am.*, vol. xvi, p. 66, 1905.

[23] *Natural Hist. of N. Y., Part IV, Geology*, p. 192, 1843; R. S. Tarr, *Elementary Geology*, p. 279, 1898; LeConte, *Elements of Geology*, p. 236, 1905.

since the problem constitutes a unit of investigation. Nevertheless there is nothing incompatible between the altitude of terrace No. 3 and a land ice-locked basin for a body of water.

DEFORMATION OF THESE OLD SHORE LINES.

From data supplied by Gilbert, it has been estimated that the post-Wisconsin deformation of the Iroquois shore line in Cayuga valley is 2.7 feet per mile.[24] Fairchild measures the warp of the Dana beach in the Seneca valley at 3 feet per mile.[25] In reference to the shore phenomena with which we are concerned the latter beach is more pertinent in location, and slightly less dissimilar in age. The pre-Wisconsin shore lines embody whatever tilting is shown by the post-Wisconsin water-levels, plus any earlier deformation that remained uncorrected by later land movements.

The shore lines shown in figs. 1 and 2 have obviously a greater tilt than has been reported for the post-Wisconsin beaches. No instrumental measurements of the deformation have been made, though an attempt was made by a long series of aneroid readings, checked with a bench aneroid,[26] to approximate a degree of correctness; but the line of contact between cliff and terrace is so obscured by products of weathering and glacial drift that it is impossible to get any results from this method, although the line is distinct enough when viewed from a distance. It is apparent to the eye that the highest, and presumably the oldest, terrace is the most warped.

The existence of these wave-cut cliffs, older than the Late Wisconsin stage, and their present attitude in reference to the horizon, suggest a relation of factors that have a bearing on a phase in the drainage history of the St. Lawrence-Susquehanna divide region, and on the question of ice-erosion in the Finger Lake valleys. A reference to the drainage problem was made under the preceding section. The connection with the ice-erosion problem, briefly stated, is this: These old cliffs imply an ice-dammed lake that

[24] R. S. Tarr, *Journal Geology*, vol. xii, pp. 79–80, 1904.

[25] *Bulletin Geol. Soc. Am.*, vol. x, p. 68, 1899.

[26] In the *Journal of Geology*, vol. xiv, p. 492, 1907, the writer explains this method of working aneroids in pairs.

was not ephemeral; the topography admits such a lake only when the ice-front is nearby. With such a position for the ice west of the Seneca valley, both it and the Cayuga valley were occupied by lobes from the main body of ice. Such lobes, it has been suggested,[27] would be competent to accomplish erosion; the non-existence of such lobes has been hypothecated on the absence of moraine belts, hence it is claimed that there was no erosion.[28] But since the stage of glaciation concerned antedated the Late Wisconsin which extended into Pennsylvania, the normal imbrication arrangement of drift sheets may explain the absence of the recessional moraine correlating with the ice-halt that was contemporaneous with the cliff-cutting and the over-steepening of the lower contours in the Seneca and Cayuga valleys by ice-erosion.

SUMMARY.

The cliffs described in this paper are the product of wave-work since they show no connection with such variation in stratigraphical structure as often produce benches, and since it has been found impossible to account for them in any other manner; furthermore, the presence of a cliff-cutting body of water is attested indirectly by other phases in the drainage and ice-erosion history of the region. That these shore lines are older than the recession stage of the Wisconsin (Late) ice sheet, follows from their being overlain by intersecting bands of Wisconsin drift.

Geological Department, Denison University, December, 1906.

[27] H. L. Fairchild, Ice Erosion Theory a Fallacy, *Bull. Geol. Soc. Am.*, vol. xvi, p. 58.

[28] *Ibid.*, pp. 59–60.

A FORM OF OUTWASH DRIFT.[1]

FRANK CARNEY.

The triangular area indicated in fig. 1 encloses a formation of outwash drift in an association undescribed in the literature so far as the writer is aware. This drift forms a terrace in the gradual slope to the north, the decline being about 500 feet in three and one-half miles. Approaching the area along the highway from Bluff Point postoffice (v. Penn Yan quadrangle, N. Y.), one notes the closeness of rock to the surface and the general absence of glacial drift. The slope, though gradual, is presumably the resultant of stream work, being the south wall of an old valley, and of ice-corrasion; but the marked change as one nears this triangle is due to an unusual accumulation of drift which is somewhat interlobate in origin; but the further differences between this and the typical outwash plain are so marked as to warrant a more definite description, and possibly a distinct designation.

TOPOGRAPHY OF THE REGION.

The drift under consideration lies on the north slope of Hall's peninsula,[2] designated on the Penn Yan quadrangle as Bluff Point, which attains an elevation of 700 feet above lake level. A nine-mile cross section, having a general east-west direction through the highest part of Bluff Point, resembles the letter "W," the inner legs being steepest but symmetrical to a vertical axis, while the left or west of the outer legs is the longer and has a gentler slope. The general relation of the two arms of Lake Keuka is strikingly suggestive of an originally south-flowing stream, the valley of which has been blocked by a great mass of glacial drift southwest of Hammondsport, a village at the southern end of this body of water, thus giving rise to the lake, which now has an out-

[1] Reprinted from *The American Journal of Science*, vol. xxiii, May, 1907.

[2] James Hall, Geology of the Fourth District, *Natural History of N. Y.*, Part IV, p. 459, 1843.

let past Penn Yan into the Seneca valley. Obviously this cross-section, W-like in shape, is made at the junction of the old south-flowing river and a tributary.

The general topography of the Finger Lake region, so frequently alluded to in geological articles, is a systematic assemblage of trough-like valleys opening into the Ontario lowland. Presumably the bed rock of these troughs slopes northward, as do also the divides between them. The Penn Yan quadrangle extends almost to the edge of this Ontario lowland. The Drumlin region reaches its maximum southern extension north of the Penn Yan sheet, and a few miles southwest of Geneva, which lies within the flaring walls of the Seneca valley.

ICE-FRONT AND DRIFT AS AFFECTED BY TOPOGRAPHY.

The Ontario lobe, as the ice which occupied this lowland is designated, maintained along its southern margin, during the advance and retreat of the ice sheet, valley dependencies, the development of which was directly in proportion to the depth of the troughs above alluded to. Of these troughs those of the Seneca and Cayuga valleys are the deepest and therefore probably were occupied longest by tongue-like projections of ice. Contiguous to these troughs are upland valleys which were also occupied by ice showing more or less dependence upon the lobes lying in the Seneca and Cayuga valleys. But as the general border of the ice retreated, the divide ridges separating these trough-like valleys were revealed farther and farther to the north between the converging lines of ice; and in an analogous manner the lesser divides marking and forming the valleys contiguous to the Cayuga and Seneca troughs became reëntrant angles between converging walls of ice. It is the work of two such lesser valley dependencies that is supposed to have given rise to the peculiar drift accumulation with which we are concerned.

A study of the drift about Penn Yan reveals a massive accumulation of débris which begins southward a mile or so from Milo Center and continues a mile or more north of Penn Yan. This moraine, approximately three miles wide, suggests a very slow

retreat of the ice in this region. It is evident also that this wide band of moraine represents more than the decay of the ice reaching out from the Ontario lobe into Seneca valley. It more likely is an indication of the general northwest trend of the ice-front crossing Flint, Naples, and Canandaigua valleys. When the ice

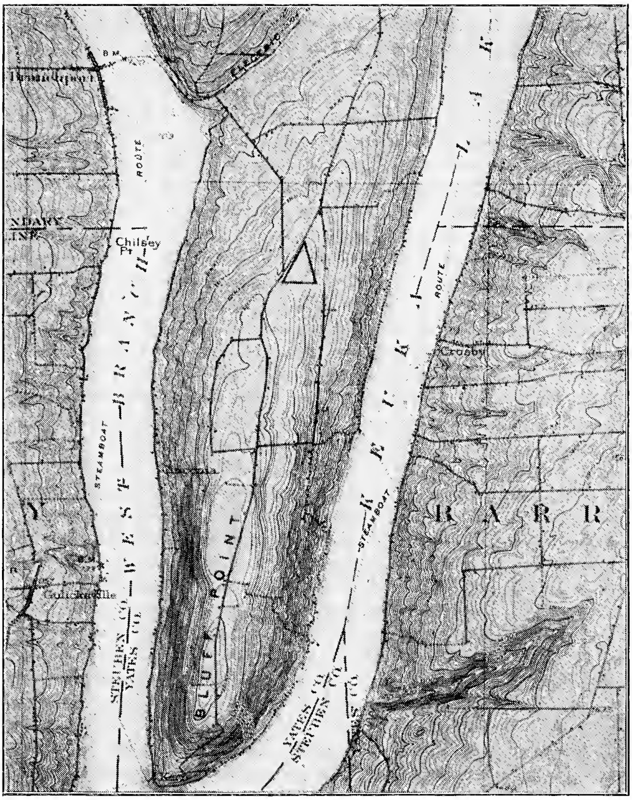


FIG. 1. A part of the Penn Yan (N. Y.) Quadrangle.

stood with a reëntrant angle approximately at Milo Center, the Seneca tongue reached many miles southward towards Watkins, while the lesser lobe in the Keuka valley was shorter. A detail of this lesser lobe evidently would give two tongues of ice, one occupying each arm of Keuka lake, with the reëntrant angle along the

north-south axis of Bluff Point, and the drift of our triangular area (fig. 1) in process of construction.

Along the margin of these valley lobes drift ridges, often widening into morainic areas, were being formed. The uniformity of such ridges as traced by Tarr on the Watkins quadrangle has suggested the characterization, "almost diagrammatic in their simplicity."[3] Each such moraine is indicative of stability in the reach of a valley lobe. Two contiguous valleys as those of Keuka and Seneca lakes would give us contemporaneously formed contouring moraines. The particular form assumed by the glacial débris at the angle of two such contiguous moraines will depend in the first place upon the northward slope of the divide; in the second place, upon the débris melted out of the ice at this particular point; and, in the third place, upon the amount of glacial drainage diverging at this point, carrying the material thus melted along the margin of the valley lobes.

From a study of these intertrough divides of the Finger Lake region, it is noted that their northward slope is gradual. The normal condition then of drift where the lateral moraines of two adjacent lobes unite reveals no special thickening. Where, however, the slope of the divide in question is steepened, and the ice immediately northward is perhaps more stagnant, or where it contains less débris, then we would anticipate a tendency toward the general removal of such débris, and the axis of the slope or divide would have less than the normal veneer of drift. On the other hand, when the axis of the northward slope is more in line with the general deployment of the ice, the chances for the accumulation of drift will certainly be enhanced. It should be noted that the northern part of the longitudinal axis of Bluff Point does trend to the east quite in unison with the direct deployment of ice from the Seneca lake lobe. This being the case then, we have the hypothetical conditions favorable to an assemblage of débris in the triangular area.

There is, however, still a further factor that favors accumulation of the drift, which is operative when the divide flattens immediately to the north, a topographic relationship due to the drainage his-

[3] *Bull. Geol. Soc. Am.*, vol. xvi, p. 218, 1905.

tory of the uplands or divide areas between these northward opening troughs. This fact taken in conjunction with the one just mentioned, that is, when the topography favors free movement from the major lobe, thus directing thitherward more active ice with this load of débris, will give us the conditions that account for the peculiar localization of the drift of the area under discussion.

DESCRIPTION OF THE DRIFT IN QUESTION.

A detailed study of this particular interlobate outwash material reveals the following facts: (1) The ice-contact face is not accentuated, that is, there is no cliff or terrace to suggest the speedy withdrawal of the ice from a position of long halt; (2) the northern part of the accumulation presents a subdued morainic surface; (3) rather numerous bowlders may be seen, some of which are the largest noted in the region. To the southward, however, this morainic topography gradually blends into a normal outwash slope. The control exercised by the falling contours of the rock slopes both east and west, is manifest in the expanding outwash when considered in connection with the moraine to which it belongs, and in the gradual falling contours of the outwash, i. e., this development of drift has something of a saddle form. Judged from the surface appearance—there is an absence of sections—the outwash material is entirely normal; there is a blending distally form coarser to finer sediments, with a few bumps suggestive of kame topography.

Proceeding southward from this area along the east slope of Bluff Point, one traces a very sharp lateral moraine marking the position of the valley tongue which occupied the Penn Yan arm of the lake contemporaneously with the building up of the outwash. This band of lateral moraine may be traced without a break until it disappears beneath the surface of the lake at a point a little south of Ogoyago. The counterpart of this band of drift on the eastern wall of the Penn Yan branch has not been traced continuously. It has been picked up, however, along the highway directly west of Warsaw, also to a point northeast of Crosby, and continuously traced where it makes the angle around the divide west of Himrods, blending then into marginal drift of the Seneca valley lobe.

But the moraine which marks the position of the valley dependency occupying the west branch of Keuka lake, at the time the outwash was developing, attained only faint expression. Its most pronounced development exists through the first mile and one-half southwest of the drift in question. From that point one cannot be certain of the outline of this valley dependency. Its form, as suggested by drift flanking the west wall of this branch of the lake, has not been investigated.

THE NORMAL OUTWASH PLAIN.

Chamberlin cites[4] references to descriptions of the general type of "glacio-fluvial aprons," variously named by geologists from 1874–1893. But a precise summary of the terminology of the deposits made by glacial waters, together with accurate distinctions on genetic and topographic principles,[5] appeared in 1902 in Salisbury's *Glacial Geology of New Jersey*, from which we quote: "Where the sub-glacial streams did not occupy sub-glacial valleys, they did not always find valleys at hand when they issued from the ice. Under such circumstances, each heavily loaded stream coming out from beneath the ice tended to develop a plain of stratified material (a sort of alluvial fan), near its point of issue. Where several such streams came out from beneath the ice near one another for a considerable period of time, their several plains, or fans, were likely to become continuous by lateral growth * * * Thus arose the type of stratified drift variously known as overwash plains, outwash plains, morainic plains and morainic aprons."[6]

This definition of an outwash plain leaves no uncertainty: genetically it results where there is a lack of alignment between sub-glacial valleys and sub-glacial loaded streams: topographically these streams should flow out upon a plain where their individual fans may coalesce. It is also evident, as Salisbury states elsewhere,

[4] Glacial Phenomena of North America, in Geikie's *The Great Ice Age*, footnote p. 751, 1894.

[5] Brief descriptions are also given in Chamberlin and Salisbury, *Geology*, vol. i, p. 306; vol. iii, p. 372, 1906.

[6] *Geological Survey of New Jersey*, vol. v, pp. 128–129, 1902.

that the degree of development of this drift-form varies with the time the ice stands at a given halt.

Woodworth alludes[7] to a washed drift which confronts the terminal moraine on Long Island; this formation, as described, is a normal outwash plain.

In his description of the drift in southern Wisconsin, Alden[8] describes an "outwash apron" which constitutes a portion of the deposits in the interlobate angle between the Lake Michigan Glacier and the Delavan lobe; his usage of the term outwash elsewhere in the paper is also in accord with the standard of definition.

In applying this definition to the localization of drift referred to on the north slope of Bluff Point, we note the following facts: (1) the absence of an initial plain, (2) the probable absence of a strong sub-glacial stream, (3) a constancy in the position of adjaent ice-lobes which built up lateral moraines, (4) a synchronous accumulation of débris at the reëntrant ice-angle, (5) diverging slopes to the south that insured rather active drainage away from this angle, and (6) a single alluvial fan-like body of washed drift blending northward into moraine.

The normal outwash plain is an assemblage of such alluvial fan-like units. The drift in question is quite identical with an outwash plain in structure, but different from it in degree of development and in topographic environment; ignoring the latter discrepancy, we may say it is a very subdued form of outwash plain that represents a constant position of the ice at the junction of two rather small valley dependencies.

Since Bluff Point is a not uncommon type of topography in the Finger Lake region, and since the writer has mapped on the Moravia quadrangle similar deposits of drift, he suggests, as a designation for such deposits, the term *inter-lobule* (or inter-tongue) *fan*.

Geological Department, Denison University, January, 1907.

[7] N. Y. State Mus., *Bulletin 84*, p. 90, 1905.
[8] Professional Paper, No. 34, *U. S. Geol. Surv.*, pp. 31–32, 1904.

STATE GEOLOGICAL SURVEYS AND PRACTICAL GEOGRAPHY.[1]

FRANK CARNEY.

The expression "practical geography," as used in this paper, implies, not essentially the utilitarian or economic phase of the subject, but the rational as opposed to the idealistic, the possible as opposed to the highly improbable or impossible. What we would accomplish in the way of right geography, and what, as a matter of fact, we are able to accomplish in the near future, are disproportionate quantities. But we do not desire the idealist to become less active; he is the standard-bearer, and when at some future time this country shall have attained the position in geography even now reached in England, we may grant that the man who always advocated the very best did more than half the work. In the meantime, it may not be futile to point out some lines of activity possible for Geological Surveys, organizations already well established and sustained in many of the States. Not only these organizations, but many others, both State and national, are constantly producing much matter that is strictly geographic, but which for purposes of geography is unused and will continue useless till properly correlated. The correlation of this material, and the accomplishment of a few other suggestions, appear to the writer practicable at the present time.

No one would underestimate the progress being made in this country in geography. The encouraging conditions furnish an incentive to hasten much better conditions. In our colleges and universities are a number of men employed solely for giving instruction in geography, and other institutions are considering the establishment of chairs. Even in secondary schools the physiographic side of geography, at least, is receiving more attention. The

[1] Written for the Chicago Meeting, 1907, of the Association of American Geographers. Reprinted from the *Bulletin American Geographical Society*, vol. xl, September, 1908.

organization of local geographic societies is another evidence of progress.

Of the various agencies through which further and more prompt progress may be effected, the Geological Surveys seem the most worth while considering. If by some necromancy we might at once bestow upon all individuals who are now giving instruction in geography a good training, making them reasonably well-equipped geographers, even such proficiency as domestic institutions can give, we would look no further. For the trained progressive teacher the innovations outlined in this paper have no personal application. In the following paragraphs I briefly consider six ways in which the Surveys might further the interests of geography:

Publications for teachers. The publications of our State Surveys contain much that is useful to the secondary school teacher; this is especially true of the economic reports, though there is an objection common to nearly all these publications; they are prepared for the class of critical and informed readers represented by the authors of the reports. No one would suggest that in this respect Surveys should deviate from the present method; such reports must not only be abreast of their phase of the science, but should also make contribution to it.

Nevertheless, it is evident to all that reports of this type can not be of greatest benefit to the average teacher of geography, and it is this teacher with whom we would labor in advancing scientific geography. To this end might not our Surveys prepare special and supplementary reports specifically for teachers? If these teachers as a class were readers of the geographical journals, the desired object might be partially accomplished; but we know they are not; furthermore, publications prepared by their own State for them in particular would make a more certain appeal. The publications I have in mind should be of two types:

a. As illustrating the class of special reports, one of these should aim at instilling a better concept of geography as a science. There is no lack of general books of method in geography, but we need terse treatments of the basal principles that should govern instruction in regional and systematic geography, emphasizing

the interrelation between the organic and inorganic parts of the subject, and impressing the necessity of a strict terminology. While in a few text-books some or all of these ideas may be exemplified, they are not given the prominence that insures an appreciation of their importance.

b. Supplementary reports summarizing for teaching purposes the more extended publications would be of great aid to the schools. For example: In recent years several States have issued extensive studies on their clays and clay industries. In nearly every case these were prepared by specialists; they contain much that is purely technical, besides facts that contribute to human relations; the facts bearing on geography admit of correlation, affording in particular an opportunity to emphasize the organic.

Some States have issued reports on one or another phase of physiography; others are engaged on more extensive physiographic studies. These contemplated publications may be strictly physiographic, embodying only the inorganic, in which case they will disregard half their scope for usefulness in the schools.

Type sets of topographic sheets. The laboratory manuals in physiography leave no occasion for reference to this topic, so far as classes in that subject are concerned. It is seldom, however, that we find topographic sheets used with classes in elementary geography. These younger pupils, consequently, do not get any conception of the map representation of relief. For their teachers, for the classes, and for older students as well, it would be a great service if Surveys were to provide at a minimum cost mounted sheets illustrating types of topography; so far as is possible, the sheets should be selected from the State concerned. Concise, lucid explanations should accompany the maps.

I am aware that teachers and school boards may secure these maps directly from Washington. But the sheets are not extensively used even in high schools. Their use would become more general if some organization of the State were to take an active interest in seeing that the proper sheets are selected, that these are made more durable by mounting, that their import is to some extent particularized upon, and that the subject of using such maps is brought direcıly to the attention of the parties who should use them.

The need of good maps in the schools was cogently amplified before this Association one year ago.[2] The best maps of home areas available are those issued by the U. S. Geological Survey; the more extensively they are used, the less will be the demand for mediocre maps.

Industrial activities. The State supplements of many school geographies usually give special attention to industrial activities; often maps are used in showing the distribution of areas of certain natural products, of the several lines of manufacturing, or particular phases of agriculture, etc. Some of this information is rendered obsolete or incomplete in a very few years; other data, usually illustrating the organic part of geography, appear, so that no matter how satisfactorily these phases of geography were treated in the original edition of the supplement, they are shortly out of date. Two or three years often witness marked changes in the activities of many localities. The fact that there has been a change is not so important in geography as the reason for the change. It is mainly in the industrial lines that innovations arise. The publishers of State supplements can not be expected to investigate and announce these activities with the promptness and thoroughness desired. State Geological Surveys can do this; furthermore, their efforts are not constrained by mercenary interests as with competing publishers.

Field work. Some years ago the New York Survey published a *Guide to Excursions in the Fossiliferous Rocks of New York State.* This little bulletin is a type of publication that other Surveys might adopt, greatly to the advantage of geography. While the schools of each region must depend largely on the immediate locality for illustrative field work, at the same time each State possesses some features, valuable for study but localized, which should be generally known.

A thickly populated part of a State suggests several lines of investigation which a Survey can treat without in the least discouraging the initiative of local teachers. It is seldom that a city is so completely self-developed that a study of its factories, etc., does not at once lead into relationships of environment, active

[2] Cyrus C. Adams, *Bull. Am. Geog. Soc.*, vol. xxxix, p. 6, 1907.

and passive. The tracing of these relationships may be a matter of considerable study, but of sufficient importance to deserve the attention; the explanatory treatment thus given a particular phase of a city's activity visited by a class is good geography.

The school museum. The school museum as an auxiliary in teaching geography is of recognized value. The large permanent museums of certain cities and of some institutions may be of inestimable aid locally, but it is a fact that such collections seldom make an appeal commensurate with their intrinsic worth, save to a few investigators or advanced students. The completeness of such museums is both an advantage and a disadvantage. It is a question whether the circulating school museum as managed in the city of Chicago is not of greater advantage for the purpose designed. The plan brings the material right into the classroom where there are no distractions arising from strangeness and from the multiplicity of objects, as is the case when the class is taken to a museum.

The assembling and management of circulating museums might be undertaken by State Surveys. Additional appropriation should be procured to start the work; if not, increased appropriations will surely come after an exemplification of its value to the schools of the State. Exchange of material between State Surveys would be the normal method of augmenting collections, particularly of natural resources. Thus rocks, ores, minerals, fossils, and illustrations of particular phenomena, as glacial scouring, and marine grinding of given areas, would be added to the collections of other States. The museums of State colleges and universities should be the clearing-houses for this material.

A participatory method might be instituted by which school boards would pay transportation charges on the collections needed. Furthermore, the schools themselves, in localities where desirable material is to be had, might be utilized in collecting for the State, at the same time encouraging the schools to arrange permanent collections.

Manufactured products, so far as is practicable, should have a large place in these collections. Every such product is either a response to a particular environment, or a less immediate and direct but no less important fact of organic geography.

Bibliographies and digests. The quantity of matter, primarily or incidentally of geographic value, issued by both government and private presses is so great that even the teacher who is giving his entire time to this study depends to some extent on the reviews and digests appearing in journals, and in bulletins of geographical societies. That the instructor who is dividing his time with other subjects can not keep abreast in geography is apparent; furthermore, it is the exception if this instructor, when he enters upon his work, is broadly acquainted with the literature. For this reason it seems advisable to place in his way the means of strengthening his preparation, and of keeping up to date. Periodical bibliographies and reviews of the recent books and articles would stimulate this activity and insure progressiveness. Surveys could exercise a selective treatment in the preparation of such bibliographies and subjects for digesting, thus eliminating the features less pertinent to the teachers and schools of their States.

CONCLUSION.

To accomplish much of this means that Surveys should employ geographers, or the best trained men that may be secured. Where this is not feasible, the coöperation and part-time assistance of men in teaching positions would be of advantage.

The outlook is encouraging, particularly where Surveys are broadening their scope by giving attention to industrial and economic activities, and by directing investigation in phases of natural history. Regional geography is thus intensified, a work which should precede a well-founded systematic geography, because a satisfactory system presupposes a consideration of a high percentage of the facts which the system would compass.

Even the little that is being done by the least affluent of our Surveys furnishes data and opportunity for advancing better methods in geography. All that is needed is an amplification of work in few lines; an emphasis wherever the schools may be reached, both in instructing and inspiring the teachers and by supplementing the outfit of the class-room; and a correlation of data produced by the Survey, and, to as great an extent as is practicable, by other similar organizations.

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FOSSILS FROM THE SILURIAN FORMATIONS OF TENNESSEE, INDIANA AND ILLINOIS

Aug. F. Foerste

The Silurian formations of Ohio, Indiana, and Tennessee contain a large fauna which awaits elaboration. Preliminary notes on some of the Tennesseean fossils were published in a paper on Silurian and Devonian Limestones of Western Tennessee, in the *Journal of Geology*, in 1903, with the expectation of their further elaboration and illustration. Plates were prepared during the following year, but not published, in the hopes of securing further material in the field. Other duties have intervened, and for some time to come will prevent further study. Under the circumstances it is considered best to publish these plates with their accompanying notes in their present condition, awaiting a future opportunity for more complete study. A part of the figures refer to fossils from Indiana, and a few of the notes include references to forms from Illinois. Several terms of a subgeneric character have been proposed. Whether these terms will commend themselves or not will depend largely upon the question whether future studies will show that they include groups which indicate close affinity and are sufficiently distinct from the types of the genera already described to warrant the separation of these groups from former genera either as subgenera or as independent genera. All the available material has been utilized in an attempt to define these groups. In most cases, the material at hand has not been of such a character as to submit to treatment by chemicals.

Cyrtoceras cinctutus, sp. nov.

(*Plate III, Figs. 37 A, B.*)

Gyroceracone; in the specimen figured the living chamber occupies a length of 30 mm. However, since the margin of the aperture is not distinctly preserved, its original length may have been greater. In a poorly preserved gyroceraconic shell from the same part of the section, with only indistinct traces of costæ, the broken

apical end, about as large as in the specimen here figured, almost touches the dorsal side of the aperture; but on account of its poor state of preservation it cannot be definitely identified with the present species; the distance between the septa is slightly greater. Annular costæ distinct at all stages of growth preserved by the type specimen, deflected toward the apical end; along the sides of the shell, between the dorsal part and the ventro-lateral angle, the curvature of costæ is fairly constant, but at the ventro-lateral angle the costæ are deflected more rapidly toward the apical end of the shell, forming a sinuate curve along the median part of the ventral side. Shell distinctly compressed laterally, the ventro-dorsal diameter of the larger end of the living chamber of the smaller fragment figured being 16.5 mm., and the lateral diameter 12.3. The costæ are more prominent at the ventro-lateral angles, adding to the flattened appearance of the sides and producing also a slightly flattened appearance along the ventral face. Along the median part of the ventral face the costæ form a deeper and more angulate sinus than do the costæ of *Cyrtoceras rigidum*; the shell is narrower, and the greater prominence of the costæ at the ventro-lateral angles is a distinguishing feature. Siphuncle ventrad of the center, about .7 of the distance from the dorsal to the ventral side, poorly preserved, apparently narrow and tubular. Septa 15 in a length of 50 mm. in the type specimen figured, the distance between the septa being greater during the ephebic stage. Internal casts of the shell and such parts of the shell as are preserved show faint transverse striations, about 30 to 35 in a length of 5 mm.; these striations are transverse to the length of the shell and maintain their directions across the costæ. In one weathered specimen there are faint traces of longitudinal striæ, but in all other specimens only transverse striæ are seen.

Osgood bed: Clifton, Tennessee.

Hyolithus cliftonensis, sp. nov.

(Plate III, Figs. 38 A, B.)

Length of more complete specimen, 32 mm.; original length possibly 38 mm.; width at the larger end, 12 mm.; width 26 mm. from the larger end, 6 mm.; vertical diameter at right angles to the width at the larger end, 8 mm. Dorsal side strongly convex, but flattened sufficiently on each side of the strongly rounded median

part to produce, in conjunction with the flat ventral side, a subtriangular cross-section. The ventral side, although strongly flattened, is slightly convex, and bears indications, along the median part, of two or three faintly defined linear, longitudinal ridges. A shallow groove, less than a millimeter from the lateral margins, gives these margins a more acute cross-section. The specimens are chiefly in the form of casts of the interiors, or, at least, do not preserve the test well. The larger specimen, however, preserves distinct traces, on the dorsal side, of numerous, close-set, longitudinal striations, alternating in size, Judging from *Hyolithus newsomensis*, these longitudinal striations may have been absent from the ventral side.

Osgood bed: Clifton, Tennessee.

Hyolithus newsomensis.

(*Plate I, Figs. 3 A, B.*)

Length, 22 to 25 mm.; width at larger end, 5.5 mm.; vertical diameter at right angles to the width, 4.2 mm. Dorsal side evenly convex, in cross-section approximately semicircular. Ventral side flattened, the median parts distinctly though moderately concave. Dorsal side striated lengthwise, about 5 or 6 more prominent striæ in a width of 2 mm., the intervals occupied by 4 to 8 finer ones; crossed by transverse striæ which are difficult to see even with a lens. Ventral side crossed by fine transverse striæ and lines of growth, and by almost imperceptible longitudinal striæ. Judging from the transverse striæ, the aperture was not oblique but opened approximately at right angles to the length of the shell.

Waldron bed: Newsom, at the old quarries half a mile south of the station; Swallow bluff, along the upper part of the bluff south of the landing; Iron City, along the top of the bluff at the station; all in Tennessee.

Diaphorostoma cliftonensis, sp. nov.

(*Plate III, Figs. 41 A, B.*)

This species has usually been referred to *Diaphorostoma niagarense*, to which it evidently is closely related. However, it is not identical, and the failure to distinguish between the two species gives them little value in determining the horizons of the rocks in which they are found. *Diaphorostoma niagarense* occurs typically

in the Rochester shales of New York, but is represented also by an almost identical form in the Waldron of Indiana and Tennessee. *Diaphorostoma cliftonensis* occurs typically in the Osgood bed of Tennessee and Indiana, but is represented by almost identical forms in the Clinton.

Diaphorostoma cliftonensis typically is a smaller shell, with a relatively greater height, compared with its width. There are about three and a half volutions, and the last volution never attains the relative width, compared with the height of the shell, which is shown by *Diaphorostoma niagarense*. Height of largest specimen, 20 mm.; width parallel to the aperture, 22 mm.; width perpendicular to this diameter, 17 mm.; height of spire above the aperture, 7 mm.; above the last volution, a little over 2 mm.; width of aperture, 14 mm.; height of aperture, about 15 mm. Shell marked by numerous faint striations transverse to the length of the volutions. There are no striations parallel to the volutions.

Osgood bed: Clifton, Tennessee.

Diaphorostoma brownsportensis.

(*Plate I, Fig. 14.*)

Shell depressed, vertically compressed along the outer margin of the last volution; a groove or depression, usually very distinct, follows the inner edge of the compressed part along the upper side of the volution; a faint depression follows the inner edge of the compressed part along the lower side of the volution. Surface marked by transverse striæ and wrinkles, which are bent back at the compressed edge of the last volution, indicating the presence of a sinus at the aperture having a maximum length of about 4 mm. Volutions about 3, contiguous, the last volution very much flattened near its beginning but less flattened toward the aperture. Resembles *Platyceras sinuatum* as represented by fig. 5, plate 55, vol. iii, of the *New York Paleontology*.[1]

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing; north of landing at Cerro Gordo; hill north of Bath Springs; all in Tennessee.

[1] James Hall, *Natural History of New York*, part vi, Paleontology, Vol. III, 1861. Whenever these volumes are referred to later in this paper they will be designated, *New York Paleontology*.

Platyceras pronum, sp. nov.

(*Plate III, Fig. 40.*)

Shell unguiform, with an ovate outline, the beak being twisted sufficiently to make it point toward the right. The shell is striated concentrically, but otherwise is smooth. Length, 28 mm.; width, 18 mm.; vertical elevation, about 11 mm.

Osgood bed: Clifton, Tennessee.

Pterinea brisa, Hall.

(*Plate IV, Fig. 61.*)

Pterinea brisa was described by Hall in the *Twentieth Regents Report* of the State Cabinet of Natural History of New York. The type was obtained at Bridgeport, Illinois. This is an entirely different species from that identified as *Pterinea brisa* from the Waldron bed, Waldron, Indiana. Only a single specimen of *Pterinea brisa* was found in the Waldson bed at Newsom, Tennessee. This was a left valve. It has the following characteristics.

Length of the umbonal ridge or general body of the shell, from the beak to the posterior end of the ridge, 20 mm. The posterior margin of the body makes an angle of about 30° with the hinge line; the anterior margin is nearly vertical. The anterior lobe begins about 9 mm. beneath the beak and extends forward about 5 mm. from the center of the beak. The extremity of the posterior lobe, along the hinge line, is about 18 mm. from the beak; the inner edge of the sinuous curve is about 16 mm. Radiating plications are numerous and sharply defined along the umbonal ridge or general body of the shell. At a distance of 11 mm. from the beak, there are 13 to 15 striations in a width of 5 mm. anteriorly, becoming less frequent and less distinct on the posterior lobe, and reduced to mere crenulations or nearly obsolete on the anterior lobe. Concentric lines of growth rise as sharp narrow laminæ, approximately equidistant on the same parts of the shell, about 12 in a length of 5 mm. at a distance of 10 mm. from the beak. These concentric striæ become more distant toward the posterior lobe of the shell, and closely crowded together on the anterior lobe. While the radiating striæ become stronger toward the anterior edge of the concentric striæ or lamellæ, they are not produced into fimbriæ.

The conspicuous features of this shell compared with the species described from Waldron are as follows. The radiating and concentric striæ are more numerous, and without fimbriæ. The anterior lobe is longer; its upper edge is more nearly parallel to the hinge margin; the sinuosity limiting it from the general body of the shell, originates farther from the beak. The posterior lobe is more extended along the hinge line. The anterior outline of the shell forms a much sharper angle with the hinge line, and the anterior height of the shell, in consequence, is less.

Waldron bed: Newsom, Tennessee.

Pterinea newsomensis, sp. nov.

(*Plate IV, Figs. 59 A, B.*)

Compared with *Pterinea brisa*, from the Niagaran of Illinois, the species described as *Pterinea brisa* from the Waldron bed of Indiana differs considerably. The relative height of the shell is much greater; the anterior outline of the shell forms a smaller angle with the hinge line; the anterior lobe extends a shorter distance from the beak, both anteriorly and vertically; the posterior lobe is less extended along the hinge line and the sinuosity along its posterior margin is less. Both the radiating and concentric striations are less numerous on the left valve, and the concentric striæ or lamellæ are more or less fimbriated where crossed by the radiating striæ, the so-called fimbriæ consisting chiefly of short denticulate projections, the margins of which are sharply turned upward. The shell attains a larger size than in the case of typical *Pterinea brisa*. The right valve is smaller, nearly flat, except toward the beak, where it is only slightly convex. Its surface is comparatively smooth along the main body of the shell, being marked only by rather distant, low striæ, which become indistinct toward the beak. The posterior lobe is marked by rather numerous sharp concentric striæ, crossed by fairly distinct radiating striæ.

Height of one specimen, 26 mm.; length along the hinge line from the anterior edge of the anterior lobe to the tip of the posterior lobe, 29 mm. The sinuous outline limiting the anterior lobe begins 6 mm. from the beak, and the extension of this lobe anterior to the general body of the shell is about 2.5 mm. Radiating striæ about 4.5 in a width of 5 mm. at a distance of 25 mm. from the beak.

Waldron bed: Newsom, Tennessee.

Pterinea nervata, sp. nov.

(*Plate IV, Fig. 60.*)

A third species of *Pterinea* found at Newsom, Tennessee, is in some respects intermediate between *Pterinea brisa* and *Pterinea newsomensis*. Its left valve is marked by radiating striæ, but these are less sharply defined than in *Pterinea brisa*, and are much less numerous. The concentric lamellæ show the fimbriate denticulations, but these are conspicuous only along the less elevated parts of the general body of the shell, where the shell is less worn. In general outline this species approaches *Pterinea newsomensis*, of which it may be regarded as a variety. However, in the case of *Pterina nervata*, when the shell is more or less worn, the general body of the left valve is seen to be covered by radiating striations of various size. The more prominent striæ number about four in a width of 5 mm., the intermediate spaces being occupied by 3 to 5 much finer striæ, visible under a lens. The species is characterized by the more distant radiating striæ, between which are a number of much finer striæ. In size, this shell equals *Pterinea newsomensis*.

Waldron bed: Newsom, Tennessee.

Rhombopteria (Newsomella) ulrichi, sp. nov.

(*Plate IV, Figs. 62 A, B.*)

In surface ornamentation this shell is closely allied to *Rhombopteria mira*, described by Barrande from the Silurian limestone of Bohemia. In our shell, however, it is the right valve which is convex and which carries the characteristic ornamentation. This consists of two systems of striations, more or less radiating, crossing each other at an angle of about 30°. In addition to this there are strong lamellose concentric lines of growth, rather distant from each other, the free edges of these lamellæ being sometimes about a millimeter in width. In one shell, the distance from the beak to the posterior end of the hinge line is 21 mm. The outline of the posterior lobe is slightly concave and makes an angle of about 45° with the hinge line. The height of the shell at the posterior extremity of the hinge line is almost 21 mm. The height where the sinuous outline of the anterior lobe begins is about 13.5. The upper part of the outline of the anterior lobe makes an angle of about 60° with the hinge line. The crossing of the

two systems of striations usually is seen best along the umbonal ridge. No left valves have been found attached to the right valves, but the left valves are believed to be less convex, with strong and distant lamellose lines of growth, similar to those on the right valves, but with radiating striations difficult to recognize even under an ordinary lens. Named in honor of E. O. Ulrich.

Waldron bed: Newsom, Tennessee.

In *Rhombopteria mira*, the type of the genus *Rhombopteria*, the straight hinge line is continued both anterior and posterior to the beak; the left valve is more convex and displays the cross-striations. With this species *Rhombopteria clathrata*, described by Weller from the Coeymans limestone of New Jersey, is congeneric. *Rhombopteria ulrichi* and *Rhombopteria revoluta* differ in the absence of the anterior projection of the straight hinge line, and in the reversal of the valves, the right valve being the more convex one and possessing the conspicuous cross-striations. If these species possess teeth, cardinal or lateral, no trace of them has been found in the specimens at hand. Posterior to the beak, the hinge area of the right valve is thickened for about half the length of the hinge line, and against this thickened area the hinge margin of the left valve rests. The term *Newsomella* is here introduced to distinguish these shells from those typified by *Rhombopteria mira*.

Rhombopteria (Newsomella) revoluta, Winchell and Marcy.

(*Plate IV, Figs. 63 A, B, C.*)

Specimens either identical with *Rhombopteria revoluta*, described by Winchell and Marcy from the Niagaran rocks of Bridgeport, Illinois, or closely related to this species, occur in the Waldron bed, at Newsom, Tennessee. The radiating striæ are much coarser; 12 to 14 striæ occupy a width of 5 mm. at a distance of 10 mm. from the beak. The striations on the posterior wing diverge strongly from those on the anterior part of the body, and along the umbonal ridge, on the posterior side of the body, the two systems of striæ cross. Cross striations are present also on the anterior lobe, only the right valve possessing these radiating striations. The striations on the posterior wing meet the hinge margin at angles of about 30° to 45°. The left valves are less convex, often nearly flat, and are marked by prominent, and rather distant lamellose concentric lines of growth. Between the latter, only

faint concentric striations are visible under a lens. This species is distinctly smaller than *Rhombopteria ulrichi*. The largest specimens do not exceed 22 mm. in length when measured along the umbonal ridge. Considering the small size of the shell, the longitudinal striations of the right valve are very conspicuous.

An examination of the cast of the type of *Rhombopteria revoluta* does not reveal specific differences between this type and the Newsom specimens, but the type is an imperfect exterior cast of the right valve only. In the Newsom specimens the shallow depression limiting the anterior lobe from the body of the shell appears more distinct, the resulting concavity of outline between this lobe and the body is more readily discernible, and the radiating striæ meet the hinge line of the posterior wing at a greater angle. If these features should prove to be fairly constant differences, when more is known of the Bridgeport species, the Newsom specimens might be called *Rhombopteria divaricata*.

Waldron bed: Newsom, Tennessee.

Conchidium legoensis.

(*Plate II, Figs. 36 A, B.*)

Closely related to *C. crassiplica*, but the shell is smaller, the plications are angular rather than rounded anteriorly, and there are 11 to 14 radiating plications, none of them bifurcating anteriorly. Length 29 to 31 mm., width 20 to 24 mm., thickness 16 to 17 mm. Brachial valve depressed along its entire length. Beak of the pedicel valve erect, apex of brachial valve concealed, sides of shell distinctly flattened posterior to the middle.

Brownsport bed: northeast of Lego on Short creek, 300 yards southeast of W. E. Ashley and P. Denman, along hillside south of the valley, Tennessee.

Conchidium lindenensis.

(*Plate II, Figs. 35 A, B.*)

In form of shell and closeness of radiating plications most nearly related to *C. colletti*, but the shell is smaller, there are only 19 radiating plications in the entire width of the shell at a distance of 30 mm. from the beak where *C. colletti* would show 34 plications; moreover, the shell is narrower, and does not possess the frequent lines of growth. Length of largest specimen, 50 mm.

Brownsport bed: east of William Goodwin on Coon creek, two and two-tenths miles east of Linden, near base of exposures on hill side, Tennessee.

Gypidula simplex, sp. nov.

(*Plate III, Figs. 51 A, B.*)

Shell small, smooth, plicated near the anterior edge. On the pedicel valve two low plications, 3 mm. apart in a shell having a width of about 21 mm., rise sufficiently to form a low median fold along the anterior third of the valve. On the anterior third of the brachial valve there is a corresponding broad shallow sinus, with a low median plication. There may be an additional smaller plication along the median line of the pedicel valve, and the median plication of the brachial valve may be divided by a narrow furrow into two plications. This shell probably is closely related to *Gypidula angulata*, Weller.

Waldron bed: Newsom, Tennessee.

Gypidula roemeri, Hall and Clarke.

(*Plate III, Fig. 51 C.*)

The shell figured here is intermediate between *Gypidula simplex* and typical *Gypidula roemeri*.

Waldron bend: Newsom, Tennessee.

Platymerella manniensis, sp. nov.

(*Plate I, Figs. 1 A, B, C, D.*)

Elongate, equally biconvex pentameroid; not galeatiform, pedicel valve not overarching, and without distinct fold or sinus; without distinct cardinal area. The beaks of the pedicel and brachial valves are practically in contact with one another, so that the delthyrium can not be seen; the beak of the pedicel valve rises slightly higher than that of the brachial valve. The dental plates of the pedicel valve are united so as to form a spondylium supported by a median septum; this septum appears to be supported along its entire length by the interior of the shell, but it is very short, about 6 mm.; the spondylium is small and appears to be confined to the immediate vicinity of the beak. Cross-sections of the shell at the beak show crural plates, moderately convergent,

extending toward the inner surface of the brachial valve, but in no case has it been possible to demonstrate that these plates reach the brachial valve and form a spondylium.

Shell apparently very thin except at the beak. Exterior marked by low, broad, and often rather indistinct radiating plications, which bifurcate in an irregular manner. In some specimens the median part of the pedicel valve is separated from the lateral parts of the shell by very slight depressions, while the median part of the brachial valve rises almost imperceptibly above the general convexity of the shell. Near the beak, the radiating plications are usually very indistinct.

Form oblong. Length of one specimen, 35 mm.; width, 28 mm.; thickness, 16 mm.

This species does not fit well into any of the divisions established for the pentameroids. It may be an ancestral form in which the spondylia are not yet strongly developed. Its affinities can not be determined more closely until the interior is better known. It is too flat for a *Pentamerella*. The absence of a straight hinge margin is characteristic. The term *Platymerella* is suggested.

Clinton bed: at foot of cliff north of railroad bridge northwest of Riverside, two miles north of Mannie, Tenn.; Cedar Point, one mile north of station at Iron City, at top of ferruginous bed, along the railroad to Pinckney, Tennessee.

? Stricklandinia dichotoma.

(*Plate I, Figs. 2 A, B.*)

Generic affinities uncertain, the interior being unknown; may be one of the *Orthidæ*, but the surface ornamentation resembles that of *Stricklandinia castellana*. Hinge line straight, delthyrium open. Valve moderately convex, 23 mm. long, 30 mm. wide, posterior half of the shell marked by about 20 radiating plications, all of which, except those nearer the posterolateral angles, branch once dichotomously on the anterior half of the shell. Plications crossed by fine concentric striæ which may escape attention if not well preserved.

Clinton bed: at Riverside and Iron City, associated with *Platymerella manniensis;* also in the Clinton at the landing at Clifton, Tennessee.

Scenidium bassleri, sp. nov.

(*Plate IV, Figs. 68 A, B.*)

Shell small, with four or five plications on each side of the median depression in the brachial valve, occasionally with two additional narrow plications on the sides of this depression anteriorly, and sometimes with a narrow intercalated plication even in the space between the first and second conspicuous plications, counting from the depression outward. The median plication of the pedicel valve is distinctly elevated. From this the shell slopes convexly toward the margins of the shell. There are four or five lateral plications on each side, and also occasionally several narrow intercalated plications, near the median parts of the shell. The characteristic features of this species are the small number of plications and the presence of very distinct concentric striæ, rather distant from each other, considering the size of the shell. Width, 5.3 mm.; length, 4 mm.; depth, 2.2 mm. Named in honor of Mr. Ray S. Bassler.

Waldron bed: Newsom, Tennessee.

Rhipidomella lenticularis.

(*Plate II, Figs. 28 A, B.*)

Largest specimen 28 mm. long, 36 mm. wide. Valves moderately convex, the greatest convexity apparently posterior to the center of the shell. Form subcircular, striæ about 160, about 12 to 14 in a width of 5 mm. The hinge line has a length of about 18 to 20 mm., the postero-lateral outline is rounded. Evidently related to *Rhipidomella circulus*, but with more numerous and finer radiating striæ.

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

Rhipidomella saffordi.

(*Plate I, Figs. 17 A, B, C.*)

A very small species; length, 8 mm.; width, 9 mm.; thickness, scarcely 4 mm. Brachial valve with a median depression which, considering the size of the species, is deep and broad. Pedicel valve evenly convex. Radiating striæ about 6 in a width of 2 mm.

Brownsport bed: in massive limestone near top of Brownsport

bed northeast of stables on Gant place, two miles northeast of Martins mills; Pegram bridge; Bath Springs; east of George Wilson, seven and one-half miles east of Savannah; all in Tennessee.

Rhipidomella newsomensis, sp. nov.

(*Plate IV, Figs. 72 A, B.*)

Among the specimens of *Rhipidomella* found in the Waldron bed, both in Tennessee and in Indiana, there is a small, strongly convex form, apparently mature, which may be distinct from *Rhipidomella hybrida*, as usually identified in the same beds. One of the largest of these specimens is 10.5 mm. long, of almost exactly the same width, being slightly wider, and its depth is 7 mm. Except in their smaller size, and mature appearance at this size, these shells do not differ from the associated specimens referred to *Rhipidomella hybrida*.

Waldron bed: Newsom, Tennessee. Hartsville, Waldron, and at the George Wright locality in Shelby county, Indiana.

Orthostrophia newsomensis, sp. nov.

(*Plate IV, Fig. 64.*)

Ventral valve moderately convex, with a wide depression along the median part toward the anterior margin of the shell. The radiate striation of the shell resembles that of *Orthostrophia halli*, judging from fig. 22, plate VA, volume viii, part i, of the *New York Paleontology*, but the individual at hand is distorted inequilaterally. At earlier stages of growth it was much more extended along the hinge line than *Orthostrophia halli* and even at maturity it is a relatively wider shell. Most of the radiating striæ branch once or twice before reaching the margin of the shell. Muscular cavity of pedicel valve small; the anterior margin only 6 mm. from the beak, considerably elevated above the inner surface of the valve, bordered laterally by the dental lamellæ and their anterior extension at the base. The greater part of the base of the muscular area is formed by a moderately concave platform separated on each side from the base of the dental plates by a narrow groove; the diductor muscular impressions are apparently much narrower than in *Orthostrophia strophomenoides*. Ovarian impressions remarkably distinct, extending about 7 mm. anterior to the hinge line and 6

mm. laterally from the muscular area; with linear dendritic ovarian striæ. Vascular markings in the form of deep grooves with few branches excepting near the anterior margin of the shell.

Waldron bed: Newsom, Tennessee.

Orthostrophia dixoni, sp. nov.

(*Plate IV, Fig. 65.*)

Pedicel valve slightly convex at the beak, flattened or slightly reversed in curvature anteriorly, but it is possible that this anterior flattening of the shell is due partly to crushing. The radiate striation of the shell is rather coarse and resembles that of an orthoid rather than that of a strophomenoid shell. There are about 6 or 7 rather broad striæ in a width of 5 mm., and these are crossed by concentric striæ and lines of growth which resemble those of an orthoid shell. Muscular area of the pedicel valve very small and remarkably deep, the base of the dental plates uniting with the curved anterior edge of the muscular area in such a manner as to produce a border sharply and considerably raised above the inner surface of the valve. The median part of the area is occupied by a low median elevation bordered on each side by a lower lateral elevation, representing the position of the adductor impressions, and occupying about one-third of the width of the area. Length of muscular area, 5 mm.; width, 6 mm. No evidence of ovarian or vascular markings. Delthyrium wide, covered by a small deltidium at the apex.

Brownsport bed: glade southwest of Dixon Spring, Tennessee.

Orthis flabellites.

(*Plate III, Fig. 43.*)

Orthis flabellites is the name suggested for the specimen represented by fig. 6, on plate 52, of volume ii, *New York Paleontology.* This is the species which occurs in the Rochester shale in New York. The species is figured also in figs. 37 to 41 on plate v of volume viii, *New York Paleontology.*

In the list of fossils from the Niagara limestones of Wisconsin, Illinois and Iowa, published in the *Twentieth Annual Report* on the State Cabinet of Natural History of New York, on p. 397, the name *Orthis flabellites* is used evidently for the northwestern form belonging to the group typified by *Orthis flabellites.* Exactly what

western form was termed *Orthis flabellites* in this list is unknown. In volume viii, *New York Paleontology*, on plate 84, Hall and Clarke figured *Orthis flabellites-spania* from the Niagara dolomites near Milwaukee, Wisconsin.

Typical *Orthis flabellites* occurs also in the Osgood bed of Indiana, from which the following description is drawn up. It is characterized by the presence of 28 to 30 simple radiating plications, separated by deep narrow grooves. Specimens with 25 to 27 plications are not rare. The brachial valve is evenly convex, having a depth of 4 to 5 mm. in shells 21 mm. in length. The convexity of the pedicel valve depends on the height of the hinge area which varies from 3.5 to 6 mm., averaging at about 4 mm. From the beak of the pedicel valve the shell slopes with a very slight convexity toward the anterior and lateral edges of the shell, but owing to the height of the hinge area, this results in giving the valve a distinctly convex form, with the point of greatest elevation at or near the beak. The hinge area of the pedicel valve forms an angle of about 60° to 65° with the plane dividing the valves. The hinge area of the brachial valve forms an angle usually of 5° or 10°, rarely of 30°. The muscular scar of the pedicel valve is of an obovate form, the sides being distinctly outlined, and converging anteriorly; the anterior termination of the muscular scar, however, usually is indistinctly outlined. When distinctly outlined anteriorly, the outline is seen to be reëntrant at the anterior margins of the diductor scars, so that the anterior margin of the adductor scars lies at the rear of this angle. The adductor scars are linear in form, and about a millimeter in width, the entire muscular area having a width of 5 mm.

Osgood bed: New Marion, Osgood, Big creek, Nebraska, in Indiana.

Orthis flabellites-militaris, var. nov.

The large form of *Orthis flabellites* found in the Clinton at the Soldiers' Home, near Dayton, Ohio, and represented by figs. 12a and 12b on plate xiii, vol. 1, of this *Bulletin*, differs chiefly in having only 20 to 24 plications, and in having a broad shallow median depression near the beak of the brachial valve, as well as may be determined from the specimens split out of the limestone. The pedicel valve is strongly convex, especially toward the beak which is distinctly incurved.

Clinton bed: at Soldiers' Home, near Dayton, Ohio.

Orthis interplicata, sp. nov.

(*Plate III, Fig. 44.*)

This form differs only in the greater number of radiating plications, a part of them being intercalated between the primary plications. In the specimen figured there are about 21 primary plications, counting all of those initiating at the beak or along the cardinal margin. In addition to these, about 19 secondary plications are added, those near the median line being added within 3 mm. of the beak, and those along the side within 5 mm. of the beak. Traces of the beginnings of several additional plications are found near the anterior edge. The interior of the brachial valve is closely similar to that of typical *Orthis flabellites.* The convexity of the valve is moderate, as in the less convex valves of *Orthis flabellites.*

Osgood bed: New Marion, Indiana.

Orthis nettelrothi, sp. nov.

The shell figured by Henry Nettelroth in *Kentucky Fossil Shells of the Silurian and Devonian Rocks*, on plate xxxiv as *Orthis flabellum*, also has intercalated plications, but it is a larger, more coarsely plicated shell from a higher horizon.

Louisville bed: from the upper part of the Louisville bed, at the Beargrass quarries, east of Louisville, Kentucky.

Hebertella (Schizonema) fissistriata, sp. nov.

(*Plate III, Figs. 45 A, B.*)

Brachial valve moderately convex, with a very shallow median depression. Cardinal area of medium height, forming an angle of about 5° with the general plane of the shell. Cardinal process formed by a thin vertical plate of moderate elevation; in addition to this plate two narrow striæ occupy the space between the crural plates, diverging from the cardinal process at an angle of about 25° to 30°. These are well developed in two specimens, but whether a constant feature of this species can not be determined at present. From the space between the crural plates, a broad median elevation extends forward to the center of the valve. The posterior adductor impressions may be traced, but the anterior impressions are very indistinct.

Pedicel valve a little more convex than the brachial valve, the cardinal area of moderate height, forming an angle of about 30° with the general plane of the brachial valve. Delthyrium wide, the sides diverging at an angle of 65°. Muscular impressions small, the anterior margin about 6 mm. from the beak; the lateral margins converging anteriorly; outline reëntrant in front of the linear adductor impressions, as in typical specimens of *Orthis flabellites*.

Radiating striations angular, increasing by intercalations at various distances from the beak. About 13 to 15 striæ originate at or very near to the beak; 28 striæ originate at least within 3 mm. of the beak, so that about 13 to 15 striæ must have been intercalated between the more primary striæ within a short distance of the beak. Additional striæ are added about 9 mm. from the beak, and along the margins of the shell a total of 60 striations may be counted. While the striæ originate in a fasciculate manner they are not sufficiently different in size, and the primary striæ are not sufficiently prominent to make the fasciculation at all conspicuous, differing in this respect from *Orthis fasciata*, Hall. Concentric striæ, if present, were not noticed on the specimens at hand.

Osgood bed: New Marion, Indiana.

The shell is not considerably thickened beneath the muscular area of the pedicel valve, as in *Orthostrophia strophomenoides*, nor are the vascular markings conspicuous. The muscular area of the pedicel valve is not conspicuously smaller than in shells of this size belonging to typical *Orthis*. For the group of shells having the structure of *Hebertella fissistriata*, with numerous intercalated striæ, with the brachial valve not exceeding the pedicel valve in convexity, but externally resembling *Hebertella*, the term *Schizonema* is suggested. This term should include apparently also *Orthis fasciata*, Hall, which is not a true *Orthostrophia*, and possibly also *Orthis fissiplica*, Roemer.

Hebertella (Schizonema) fasciata, Hall.

(*Plate IV, Fig. 71.*)

Among the specimens found in the Osgood bed, at New Marion, in Indiana, is one which closely resembles the description given of *Orthis fasciata* from the Rochester bed of New York. The postero-lateral angles are broken off so that the extension of the

hinge line beyond the general width of the shell can not be verified. The fasciation, however, is distinct, especially on the pedicel valve. About 10 striations begin at or very near to the beak, and between these an approximately equal number is intercalated almost immediately, so that about 18 fairly prominent striæ extend from near the beak to the margins of the shell. These striæ have a tendency to occur in pairs, as though resulting from the division of the more primary striæ. About 7 mm. from the beak other striæ are intercalated, and anterior to this there may be a few additional striæ, so that the anterior and lateral parts of the shell are marked apparently by fascicles of striæ, the fascicles consisting of three or four striæ near the median parts of the shell, the primary striation of each fascicle being considerably more conspicuous, as in *Plectorthis fissicosta.* The fascicles have a tendency to occur in pairs.

Length of shell, 15 mm.; width across the middle, 19 mm.; depth of the entire shell, 6 mm. The valves are nearly subequal in convexity.

Osgood bed: New Marion, Indiana.

Hebertella (Schizonema) nisis, Hall.

This species is evidently closely related to *Hebertella fissiplica,* it shows about the same range of variation in the coarseness and frequency of the radiating striæ and in the curvature from front to rear of the pedicel valve. It has the median depression of the brachial valve; the high cardinal area, inclined strongly backward, of the pedicel valve; the pedicel valve is conspicuously more convex and deeper than the brachial valve; the delthyrium is narrow.

It differs from *Hebertella fissiplica* in the greater convexity of the brachial valve and the greater height of the cardinal area of the pedicel valve. This area is more incurved near the beak in one of the specimens figured by Hall than in any specimens of *Hebertella fissiplica* so far seen. See figs. 4 to 8 on plate 9 of the Twenty-seventh Report on the New York State Cabinet.

Louisville bed: in the upper strata exposed in the quarries along Beargrass creek east of Louisville, Kentucky.

Hebertella (Schizonema) fissiplica, Roemer.

(*Plate III, Fig. 54.*)

Shell plano-convex. Brachial valve nearly flat or slightly convex with a distinct but shallow median depression similar to that of *Dalmanella jugosa*; cardinal area very narrow, deviating but slightly from the general plane of the valve; cardinal process in form of a thin, simple, vertical plate, as in *Orthis flabellites*. A thickened elevated median ridge extends from the deltidial cavity forward to a point a short distance beyond the center of the valve. Muscular impressions indistinct.

Pedicel valve convex; cardinal area high and flat, but slightly if at all incurved at the beak, forming an angle of about 110° with the general plane of the brachial valve; delthyrium narrow as in *Hebertella nisis*. In the specimens from Dixon spring, the shell is but slightly curved along the median line, from the beak to the anterior margin. In the larger specimens from Clifton, the curvature corresponds more nearly to that of *Hebertella nisis*. In general the shell slopes strongly from the beak to the lateral and anterior margins. Muscular impressions small and rounded, elevated at the margin slightly above the interior of the valve; margin slightly incurved anterior to the adductor muscle impressions; the latter are linear and occupy about one-fifth of the entire width of the muscular impressions. Size of muscular area small, corresponding to that of *Orthis* rather than that of *Hebertella*. Interior of valves radiately grooved along the border as in typical species of *Orthis*.

Radiating striæ about 22 within 4 mm. of the beak, increasing to about 45 at the margin, about 5 to 7 striæ occupying a width of 5 mm. At their origin the newer striæ are much less conspicuous than the older striæ, usually originating near the latter although sometimes inserted near the middle of the spaces between the older striæ. The older striæ are usually more conspicuous, resulting in an alternation of larger and smaller striæ or in a more or less fasciculate arrangement. Radiating striæ crossed by numerous fine, sharp concentric lines, usually well preserved between the striæ.

In fig. 5a, plate 5, of Roemer's monograph on the *Silurian Fauna of Western Tennessee*, the posterior margin along the hinge area is drawn too concave to the right and left of the beak. In fig.

5b, the reversal of curvature is due to crushing, common except in silicified shells; the cardinal area of the brachial valve should be much higher, and the inclination of the cardinal area of both valves is incorrectly indicated. Errors of this nature are shown also by other drawings accompanying this paper.

Brownsport bed: glades southwest of Dixon Spring; Clifton, west of Dr. Evans, west of Hope creek; south of Mr. Phillips, four miles northwest of Martins mills; Bath Springs; Wells creek basin, Tennessee.

Hebertella (Schizonema) celsa, sp. nov.

(*Plate III, Figs. 53 A, B.*)

Brachial valve moderately convex, with a distinct but shallow median depression as in *Dalmanella*. Cardinal area forming an angle of about 150° with the general plane of the valve. Upper margin of cardinal process narrow, projecting slightly beyond the cardinal area, marked by a faint longitudinal groove. Anteriorly the cardinal process is merged in the comparatively high median elevation which divides the muscular area. Crural plates strongly developed, their base continuous with the straight postero-lateral border of the posterior adductor impressions. Anterior margin of the anterior adductor impressions extending slightly beyond the center of the valve. Muscular impressions resembling those of *Hebertella insculpta*.

Cardinal area of the pedicel valve flat, forming almost a right angle with the general plane of the brachial valve, broadly triangular, high at the beak. The type specimen has a width of 16.5 mm., the cardinal area has a length of 13 mm. along the hinge line, and the height of the area is 4.3 mm. The width of the delthyrium is about 2.5 mm. at the widest part, at the apex it appears to possess a rather large apical plate, poorly preserved. Curvature from the beak to the anterior margin of the shell slight, the shell sloping rather evenly but abruptly from the beak to the lateral and anterior margins of the shell.

Radiating striæ rather angular, the newer striæ being implanted among the older so as to produce a fasciculate arrangement; about 8 or 9 striæ in a width of 5 mm. Numerous fine concentric striæ.

Linden bed: above quarry along river north of Perryville, Tennessee.

Chonostrophia lindenensis, sp. nov.

(*Plate III, Fig. 52.*)

Shell with extremely fine, filiform radiating striæ, visible under a lens. Pedicel valve slightly convex near the beak and slightly concave as a whole. Width, 23 mm.; length, 11 mm. The great width of the shell, compared with its length, will distinguish it readily from any species described hitherto.

Linden bed: Pyburn bluff, Tennessee.

Triplecia (Cliftonia) striata, sp. nov.

(*Plate III, Figs. 42 A, B.*)

The external aspect of this species is that of a small *Atrypa*, but the internal structure indicates close relationship to *Triplecia*.

Brachial valve circular in outline; pedicel valve more nearly ovate. Brachial valve strongly convex, raised so as to form a low broad median fold anterior to the middle. The shell starts at the beak with a median groove which is rather conspicuous along the posterior third of the shell. Pedicel valve rather strongly convex posteriorly, but bent downward anteriorly so as to form a broad shallow median depression, not always symmetrical. Radiating striæ rather coarse and distant considering the size of the shell, about 7 to 9 in a width of 5 mm. Concentric striæ probably were distinct on the original shells. Length of the pedicel valve, 13 mm.; width, 13 mm.; depth, almost 3 mm. Length of brachial valve practically the same as that of the pedicel valve, but the depth is almost 6.5 mm.

Interior of brachial valve with a linguliform cardinal process, 1.7 mm. in length, and $\frac{3}{4}$ mm. in width at the hinge line. This process becomes broader anteriorly, and divides near the tip into two short, sharply pointed, divisions. The impressions of two short sharply pointed cruræ are seen in one of the specimens. There is a narrow median striation along the posterior third of the interior, corresponding to the median groove on the exterior. The interior cast of the pedicel valve indicates the presence of a rather high flat hinge area, whose length is about 8 mm. in a shell 13 mm. wide. The height of this area is estimated at almost 2 mm. A conspicuous cavity extended from the interior of the shell along the part enclosed within the beak, and opened by means of a small aperture at the tip of the beak. Teeth supported by short dental

lamellæ which are only 1.5 mm. in length, and are separated anteriorly by a space about 1.4 mm. in width. A sharp striation borders the sides of the aperture leading to the beak.

Clinton bed: south of the old abandoned Cement Mill, south of Clifton, Tennessee.

The type of *Triplecia* is *Triplecia extans*, a smooth shell. From this *Triplecia striata* differs sufficiently in general appearance to warrant the erection at least of a subgeneric term. For the striate species, resembling *Triplecia striata*, the term *Cliftonia* is here suggested. Possibly *Triplecia niagarensis*, Hall and Clarke is congeneric.

? Triplecia (Cliftonia) tenax, sp. nov.

(*Plate III, Fig. 36; Plate IV, Figs. 70 A, B.*)

Shell with the external aspect of a *Hebertella*, but apparently so similar in form to *Triplecia* (*Cliftonia*) *striata*, that these shells are regarded as very closely related, although the interior structure of *Triplecia tenax* is not known. Compared with *Triplecia striata*, *Triplecia tenax* is a larger, broader, and less strongly convex shell. It possesses the low broad median fold on the anterior part of the brachial valve, and the broad, shallow depression along the anterior part of the pedicel valve. The median groove toward the beak of the brachial valve is distinct. The hinge area on the pedicel valve is well defined, but nothing is known about the delthyrium. The radiating striations are distinctly stronger than in *Triplecia striata*, especially in case of the primary striæ. Between 6 and 7 striations are found in a width of 5 mm. Concentric markings indistinct on the considerably exfoliated surface of the shell.

Length, 13.5 mm.; width, 18 mm.; depth, 9 mm. Length of hinge line, 10 mm. Height of hinge area, about 1.6 mm. Convexity of valves approximately equal. Radiating striæ increased by implantation of additional striæ at various distances from the beak, resulting in a fasciculate arrangement.

Osgood bed: Clifton, Tennessee.

Schuchertella roemeri.

(*Plate II, Figs. 27 A, B, C.*)

Shell evidently related to *Orthothetes subplanus* with which it usually is identified, but the shell is smaller, the number of radiating plications is smaller, and the intermediate spaces much broader.

Width, 28 to 30 mm. This is evidently the species identified by Roemer with *Orthothetes subplanus.*

Brownsport bed: glade southwest of Dixon Spring, also at Pegram, Tennessee.

Plectambonites tennesseensis.

(Plate I, Figs. 5 A, B, C, D, E.)

Width, 7 to 9 mm.; convexity, 2.2 mm.; pedicel valve with 5 more conspicuous radiating striæ, distinct even near the beak, the intermediate spaces occupied in each case by a single radiating striation which extends only halfway from the margin of the shell toward the beak. Finer radiating striæ practically obsolete. Cancentric markings of the shell rather distant, distinct, due to difference in color caused by clay entering the thin spaces left at different stages of growth.

Waldron bed: Iron City, at Cedar Bluff, also at the station; Swallow Bluff; along the river three-quarters of a mile above the landing at Clifton; along the road leading east from New Era; Newsom; all in Tennessee.

Strophonella tenuistriata, sp. nov.

(Plate II, Figs. 20 B, A.)

Evidently related to *Strophonella roemeri*, but the shell is smaller, the outline is more semicircular, and the curvature of the shell where it is deflected anteriorly is much more moderate and not at all sufficient to be called geniculate. Width, 31 mm.; length, 20 mm. Brachial valve distinctly concave over the larger part of the flattened area anterior to the beak, reversal of curvature beginning about 10 or 11 mm. anterior to the beak. Pedicel valve distinctly convex for a distance of about 8 mm. anterior to the beak, the remainder following the curvature of the brachial valve. Surface with fine radiating striæ, 5 to 8 more prominent striæ in a width of 5 mm., separated by 3 to 6 finer striæ. Inner surface granulose. This is probably the species identified by Roemer with *Strophonella euglypha.* His specimens were fragmentary, his figures were restored, and the curvature of the shell as indicated by fig. 3c, plate 5, of his work, *Silurische Fauna des westlichen Tennessee,* is probably incorrect at the anterior extremity; if the anterior part, 5 mm. long, were omitted, the figure would be a fair

representation of the curvature of the Tennessee specimens. Our fig. 20 A is taken from a specimen which evidently equaled his fig. 3b in size.

Brownsport bed: on hill side south of road leading east from New Era; also north of landing at Cerro Gordo, Tenn.; and in massive limestone northeast of stables on Gant place northeast of Martins mills, Tennessee.

Strophonella williamsi, described by E. M. Kindle from the Silurian of northern Indiana, appears to be a much more convex species, when viewed from the side of the brachial valve.

Strophonella roemeri.

(*Plate II, Fig. 24.*)

Shell subtrigonal in fully developed specimens, probably more semicircular in young specimens, the subtrigonal form being due chiefly to the greater growth of the shell along the anterior edge and the rapid deflection of the shell antero-laterally. Width at hinge-line 56 mm.; brachial valve distinctly flattened anterior to the beak for a distance of about 18 to 20 mm., slightly concave toward the beak, abruptly deflected anterior to the flattened area, the deflection being greater toward the antero-lateral margin than toward the anterior median parts of the shell. Antero-lateral slopes more or less flattened. From the anterior part of the flattened area to the anterior part of the shell may be a distance in the largest specimens of 37 mm., but usually 34 to 30 mm., or even less. Pedicel valve slightly convex near the beak, following the curvature of the brachial valve. Cardinal margin crenulated for a distance of about 7 mm. on each side of the delthyrium. Muscular area of pedicel valve 13 mm. long, 16 mm. wide, lateral margins thickened and raised abruptly above the inner surface of the valve, open along the median line anteriorly; adductor scars distinctly defined posteriorly by low elevations which begin at the beak and branch within 1 mm. of the same, the two exterior branches defining the postero-lateral margins of the scar, the two inner and much shorter branches defining the inner margins at the posterior extremity. Between the two inner branches arises the narrow median elevation which divides the adductor area. Inner surface granulose, the granules arranged in lines approximately following the exterior ornamentation of the

shell; this granulated area passes behind the muscular area and almost reaches the beak. A profile view of the pedicel valve resembles fig. 4c of plate 23, vol. iii, of the *New York Paleontology*. Surface with radiating striæ, about 7 to 10 more prominent striæ in a width of 10 mm., separated by 4 to 8 finer striæ.

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

Strophonella prolongata.

(*Plate II, Figs. 23 A, B.*)

Width, 31 mm.; length, 15 mm. Shell broadly sub-semicircular, considerably extended along the hinge line; brachial valve flattened for a distance of 10 or 11 mm. anterior to the hinge line, slightly concave toward the middle of this surface; anterior to the flattened area the shell is deflected almost vertically, producing a profile similar to that of fig. 6c, plate 23, vol. iii, *New York Paleontology*. Pedicel valve slightly convex anterior to the beak, following the curvature of the brachial valve; cardinal line crenulated for a distance of about 3 mm. on each side of the delthyrium; interior showing the character of the striation of the exterior surface distinctly; muscular impressions not distinct, a faint median elevation, and two faint elevations defining the postero-lateral margins of the muscular area. Surface with radiating striæ which are rather coarse and prominent considering the size of the shell, about 18 to 21 in a width of 10 mm. along the anterior margin.

Brownsport bed: glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

In the massive limestone layer near the top of the Brownsport bed, northeast of the stables on the Gant place, northeast of Martins mills, a specimen is found which shows a strong median depression on each side of which the shell is slightly raised. It is represented by fig. 22 on plate ii, of this paper and evidently resembles *Strophonella geniculata*, fig. 6, plate 23, vol. iii, *New York Paleontology*. The striations are coarser. The specimen is poorly preserved.

Strophonella dixoni, sp. nov.

(*Plate II, Fig. 21.*)

Evidently related to *Strophonella prolongata*, but smaller. Width, 16 mm.; length, 7 mm.; brachial valve flattened and slightly con-

cave anterior to the hinge line, the flattening extending for a distance of almost 6 mm. anterior to the beak; at this point the shell is strongly curved, the anterior part of the shell being deflected almost vertically downward. Pedicel valve following the curvature of the brachial valve. Radiating striæ strong and coarse considering the size of the shell, about 11 in a width of 5 mm. along the anterior margin.

Brownsport bed: glade southwest of Dixon Spring, also at Clifton, Tennessee.

Strophonella ganti, sp. nov.

(*Plate II, Fig. 22.*)

Shell small, about 16 mm. in width along the hinge line, and varying from 8 to 10 mm. in length. Resembling *Strophonella geniculata*, Hall, from the Lower Helderberg, in having a broad median depression along the brachial valve, becoming stronger toward the geniculate border. The striations appear to be rather coarse, as in *Strophonella prolongata.* There is not sufficient material to establish the validity of this foim as a species.

Brownsport bed: in the coarse sandy limestone at the base of the Gant layer, forming the upper part of the Brownsport formation, at the A. B. Gant place, and at Martins Mills, Tennessee.

Strophonella laxiplicata.

(*Plate II, Fig. 25.*)

The most perfect specimen appears to be only a young form of this species. The brachial valve is slightly concave, and the pedicel valve is moderately convex anterior to the beak. The reversal in curvature takes place about 11 mm. anterior to the beak. The most characteristic part of the shell is the nature of the radiating striæ. The striæ are rather sharply elevated above the general surface of the shell; and are separated by comparatively wide spaces in which finer intermediate striæ are absent or practically obsolete. Only a small number of striæ, usually less than 10, begin at the beak, and new plications are added usually by intercalation, appearing near the middle of the comparatively wide intermediate spaces. Cardinal area striated vertically. Radiating striæ crossed by fine concentric striæ which are seen only under a lens, chiefly in the spaces between the striæ. Width of type

specimen, 21 mm. At Brownsport Furnace, three miles west of Vice landing, a specimen having the characteristic surface ornamentation of this species, but at least 37 mm. wide, was found.

Brownsport bed: Brownsport Furnace, Tennessee; Cerro Gordo; Bath Springs; east of George Wilson, seven and one-half miles east of Savannah, Tennessee.

Strophonella semifasciata-brownsportensis, var. nov.

(*Plate II, Fig. 26.*)

At Brownsport a single fragment was found of a *Strophonella* in which the spaces between the more prominent striæ are very wide. The finer intermediate striæ usually found are entirely obsolete in this specimen. Between the stronger striæ already mentioned the spaces are either flattened or broadly concave. The striæ tend to become indistinct toward the beak. Although represented only by a small fragment, the specific characters are striking. Its nearest relative is *Strophonella semifasciata*, Hall, from the Waldron bed, of which it may be only a smaller variety.

Brownsport bed: Brownsport, Tennessee.

Stropheodonta (Brachyprion) newsomensis, sp. nov.

(*Plate IV, Fig. 67.*)

Stropheodonta newsomensis is a smaller species than *Stropheodonta profunda* from the Clinton of New York. While occasional specimens are quite strongly convex, the convexity of the greater number is not sufficiently great to warrant the term profound. In the type of *Stropheodonta profunda* the convexity is stated to be three-fourths of an inch, the length of the shell, as determined from the accompanying illustration, being 43 mm., and the width 53 mm. across the middle. A large sized, rather strongly convex, specimen of *Stropheodonta newsomensis* has a length of 33 mm., a width of 36 mm. across the middle and 40 mm. at the hinge, and a depth of about 11 mm. The valves are thin, and the space between them scarcely exceeds 3 mm. nearer the hinge line and 1 mm. anteriorly. The convex ventral valve is marked by fine and rather distant radiating striæ, between which there are sets of three or four still finer striæ. Toward the anterior and lateral margins these striæ become larger and more nearly subequal, or alternately large and small. The larger striæ near the

margin number about 11 in a width of 5 mm. The radiating striæ on the dorsal valve are still finer. The concentric striæ on both valves can be seen only with a lens.

The interior of the pedicel valve shows the crenulations on the cardinal margin for a distance of about 4 mm. from the delthyrium. The muscular area is triangular flabelliform, well defined laterally but not anteriorly. A median ridge divides the posterior part of this area, and near the beak this thickens into a callosity filling the median part of the space between the hinge teeth. From this callosity two short ridges diverge anteriorly, in addition to the median ridge.

The cardinal process of the brachial valve consists of two lobes, slightly over 2 mm. long, diverging at angles of 50° from each other, in a plane at right angles with the shell. Anterior to the cardinal process, the shell is thickened so as to form a subrhomboidal space, anterior to which there are only faint traces of muscular impressions. The posterior parts of the brachial valve, and also of that part of the pedicel valve which lies outside of the muscular area, are marked by coarse granules, becoming more numerous and finer anteriorly. In some shells only the coarser granules are present.

Waldron bed: Newsom, Tennessee.

Meristina maria-roemeri, var. nov.

(*Plate II, Fig. 29 A, B.*)

This species is evidently closely related to *Meristina maria* of the Waldron horizon, but is readily distinguished by its subtrigonal outline, especially when viewed from the side of the pedicel valve. This subtrigonal outline is produced by a straightening of the postero-lateral outline. The strongly sinuous outline of the anterior margins of the valves is normal in this form while in typical forms of *Meristina maria* it usually is less developed. See fig. 12, plate 5, of Roemer's work in the *Silurian Fossils of Western Tennessee.*

Brownsport bed: north of landing at Glenkirk, at mouth of Beech creek; glade southwest of Brownsport Furnace, three miles west of Vice landing; mound glade half a mile west of road, two and one-half miles north of Vice store; Martin's Mills; old Colonel Jim Smith's place, nine miles east of Savannah; bridge two miles west of Pegram; all in Tennessee.

Anoplotheca saffordi.

(*Plate I, Fig. 6.*)

Length, 5 mm.; convexity, 2.8 mm. Pedicel valve strongly convex, with the 3 median radiating plications (the middle one narrower) forming an indistinct elevation, with 4 distinct and one indistinct plication on each side; the beak projecting but slightly beyond that of the brachial valve. Brachial valve concave, especially anteriorly along the shallow median depression; depression occupied by 2 radiating plications placed close together and separated by a short space from the lateral plications of which 4 are distinct and one indistinct.

Brownsport bed; in the massive limestone near the top of the Brownsport exposure, northeast of the stables on the Gant place, northeast of Martins Mills; Bath Springs; east of George Wilson, seven and one-half miles east of Savannah; all in Tennessee. The same species, described as *Anoplotheca congregata*, by E. M. Kindle, occurs in the Kokomo limestone at Logansport, Indiana.

Homœospira schucherti.

(*Plate I, Figs. 10 A, B.*)

Shell broadly ovate; length of one of the type specimens, 11 mm.; width, 10.3 mm.; thickness, 6.8 mm. Both valves with a shallow median groove or depression most distinct anteriorly, usually occupied by one or two plications originating in the groove a short distance anterior to the beak, less distinct than the remainder; about 7 distinct and 1 indistinct radiating plications on each side of the median groove. Length of largest specimen seen, 13 mm.; named in honor of Mr. Charles Schuchert.

Brownsport bed: Brownsport Furnace, Tennessee.

Homœospira schucherti-elongata, var. nov.

(*Plate I, Figs. 9 A, B.*)

Shell smaller, narrower, median groove more distinct, radiating plications usually narrower and closer together, as in fig. 9 B; about 8 distinct plications on each side of the median groove, with one or two less distinct plications within or along the walls of the groove. Shell narrower and more convex from side to side, the beak of the pedicel valve more incurved over that of the brachial

valve. Length, 9 mm.; width, 7.6 mm.; thickness, 6.2 mm., in one specimen. Apparently connected by intermediate forms with *Homœospira schucherti*, although extreme forms are readily distinguished.

Brownsport bed; north of the home of W. N. Davis, Bath Springs, Tennessee, associated with *H. schucherti*.

Homœospira beecheri.

(*Plate I, Figs. 8 A, B.*)

Very small; length, 6.5 mm.; width, 6 mm.; thickness, 3.5 mm. Convexity of shell rather small, form broadly ovate, radiating plications more distinct at the beak than in *H. schucherti*, 6 distinct and 1 indistinct plication on each side of the median groove. Beak of the pedicel valve erect, raised above that of the brachial valve, not strongly infolded. Median groove of brachial valve scarcely larger than that between the plications nearest the groove, occupied by a single very narrow plication which anteriorly divides into 2 very narrow parallel closely set plications very easily overlooked. Median groove of ventral valve broader, occupied by two narrow plications, much narrower than the plications on each side of the median groove, but much more distinct than those occupying the base of the groove in the brachial valve. Named in honor of Mr. Charles Beecher.

Brownsport bed: glade southwest of Brownsport Furnace, west of Vice landing, Tennessee.

Homœospira pisum sp. nov.

(*Plate I, Fig. 7.*)

Shell smaller and more convex than any of the forms described above. Length, 6.3 mm.; width, 5.5 mm.; thickness, 4.5 mm. Lines of growth numerous near the anterior margin; shells evidently mature notwithstanding their small size. Beak of pedicel valve either curving strongly over that of the brachial valve, or lifted considerably above the latter and only moderately overarching the same. Median groove of both valves distinct; 2 very narrow plications occupy the median groove of the brachial valve, while the two plications which are inserted along the median line of the pedicel valve a short distance from the beak almost equal

the other radiating plications in size anteriorly, and are but slightly depressed below the level of radiating plications on either side. About 6 distinct radiating plications on each side of the median groove.

Brownsport bed: Bath Springs, Tennessee.

A study of the various specimens of *Homœospira* at hand suggests that there is considerable variation in the appearance of the plications which occupy the median groove even within the limits of the same species so that characters drawn from this source are considered of doubtful value. A single plication may begin at different distances anterior to the beak and may or may not bifurcate anteriorly; in case it bifurcates the two branches may be very fine and remain very close together, or they may separate more or less; they may separate so far as to occupy a position along the side walls of the groove. In some cases these median plications may so nearly equal the size of the plications on either side that only their later insertion at a greater distance from the beak distinguishes them readily. Sometimes two plications are inserted side by side along the median groove and increase in size anteriorly or remain comparatively small. Nevertheless differences in form are noticed which are sufficiently constant to suggest the presence of different species. These differences consist chiefly in differences in the lateral outline, the convexity, and the coarseness and distinctness of the plications. The amount of overarching of the beak of the pedicel valve varies considerably in the same species.

Cyrtia cliftonensis.

(*Plate II, Fig. 32.*)

Height of cardinal area, 6 mm.; width, 10 mm.; margins of sinus of ventral valve distinct and angular, diverging at an angle of about 52°; lateral outlines of the cardinal area form an angle of about 82° at the beak; the cardinal area forms an angle of about 69° with a plane resting upon the margins of the sinus. Although the sinus is sharply defined laterally, it is of only moderate depth; in a similar manner the elevation of the median fold on the dorsal valve is moderate. Surface with very fine radiating striæ, seen only under a lens. Width of delthyrium at hinge line about 1 mm.; foraminal groove of the deltidial covering apparently very long and narrow but not well preserved.

Brownsport bed: Clifton, at the top of the hill back of the town, Tennessee.

Reticularia pegramensis.

(*Plate II, Fig. 31 A, B.*)

Length, 15 mm.; width, 19 mm.; thickness, 10.5 mm. Valves subequally convex; median fold of brachial valve low but distinct owing to a slight depression of the shell along each side, width of fold 5 mm. at the anterior margin of the shell; median depression of the pedicel valve shallow. No lateral folds or plications. Surface with concentric markings as in *Reticularia fimbriata*. Sides of the fold diverging at an angle of about 20°. Probably identical with *Reticularia proxima*, described by E. M. Kindle from northern Indiana.

Brownsport bed: Pegram, Tennessee.

Spirifer geronticus.

(*Plate II, Fig. 30 A, B.*)

Width of largest specimen found, 24 mm. Fold of brachial valve, low, rendered more distinct by a narrow depression of the shell or groove, on each side; sides of fold diverge at an angle of 27°; the groove is most distinct at the beak. On each side of the fold is a plication which is distinct at the beak but becomes faint and disappears about 14 mm. from the beak; a second plication on each side becomes faint about 4 mm. from the beak. Sinus of the pedicel valve sharply defined laterally, the margins of the same being formed by a plication which is distinctly defined by a groove along its posterior part, the groove becoming less distinct anteriorly. In addition to the plication which borders the sinus there is a second plication on each side which disappears about 6 mm. anterior to the beak. It is evident that the shell possesses a larger number of plications in its earlier stages of growth than it continues to develop during its later stages, the ornamentation becoming more simple at maturity. Surface with numerous fine radiating striæ.

Brownsport bed; glade southwest of Dixon Spring; hill east of Clifton; four miles northwest of Martins Mills; south of Mr. Phillips'; Pegram, Tennessee.

Spirifer swallowensis.

(*Plate II, Fig. 33.*)

Resembles *Spirifer crispatus*, but, in addition to the median fold of the brachial valve and the two plications forming the sides of the median sinus on the pedicel valve, there is on each side only one well developed lateral plication in place of two as in the case of *Sp. crispatus*, and the concentric lamellæ appear coarser. Length, 11.5 mm.; width, about 14 mm.; thickness, 9.5 mm.

Waldron bed: Swallow Bluff, north of landing, Tennessee.

Atrypa reticularis-newsomensis, var. nov.

(*Plate I, Figs. 11 A, B.*)

The assigning of a distinct name to this very common form of *Atrypa reticularis* is due merely to the convenience which a distinct name offers when it is desired to record in the field the particular variety which is present at any locality. It is not expected that this name will find general use. Radiating plications coarse, 8 or 9 in a width of 10 mm. Shell of medium size. Types from Waldron bed at Newsom, Tennessee.

Atrypa reticularis-niagarensis was figured by Nettelroth in Fossil shells of the Silurian and Devonian rocks of Kentucky, 1889, plate 32. There are from 12 to 14 plications in a width of 10 mm. The form of the shell is more variable than the figures by Nettelroth suggest. It is the form figured by Roemer, fig. 9, plate 5, in his work on the *Silurian Fossils of Western Tennessee.*

Atrypa arctostriata.

(*Plate II, Figs. 34 A, B.*)

Probably only one of the many varieties of *Atrypa reticularis* but apparently more distinct than the greater number of these forms. About 28 radiating plications in a width of 10 mm. Fimbriate margin at different stages of growth well preserved. Shell of only moderate convexity, a specimen 15.5 mm. long and 18.5 mm. wide having a vertical dimension of only 7.5 mm.

Brownsport bed; glade southwest of Brownsport Furnace, three miles west of Vice landing, Tennessee.

Rhynchotreta simplex, sp. nov.

(*Plate III, Figs. 46, A, B.*)

Shell triangular, cuneiform, tapering posteriorly into an angular beak. Width of one specimen, 11 mm.; thickness, 5 mm.; length, estimated at 13 mm. Both valves moderately convex. In the pedicel valve the teeth are supported by thin vertical lamellæ which border a long, narrow, deep pedicel scar; muscular impressions faint, probably 3 mm. long, extending to within 8 mm. of the anterior margin of the shell. Brachial valve with a median septum Cardinal slopes long and flattened. Plications about 12; no evidence of fold or sinus. Shell apparently remaining in the neanic stage. No reversal of curvature is noted.

Compared with *Rhynchotreta transversa*, Weller, this species has a greater number of plications.

Clinton bed: from the weathered brown chert found near the cement mill, at the southern end of Clifton, along the river. Tennessee.

Rhynchotreta thebesensis, sp. nov.

(*Plate IV, Figs. 66, A, B, C.*)

Shell cuneiform, with long flat sides diverging at an angle of 60° to 70°, with an acuminate beak. The anterior outline is rounded, and the depth of the shell is considerable for one of this type. In a shell having a width of 14.5 mm., the depth was 10.5 mm., the length of the brachial valve was 14.5 mm., and the length of the pedicel valve was estimated at slightly over 15.5 mm. Near the beak of the brachial valve a few specimens show a slight median concavity. The two median plications are slightly raised anteriorly above the general convexity of this part of the shell. On each side of these median plications there are four distinct and 1 indistinct plication, reduced sometimes to 3 distinct and 1 indistinct one. On the pedicel valve there is a median plication with 4 distinct and 1 indistinct plication on each side. This median plication, in some specimens, terminates in a slight depression anteriorly, in others the plication on each side of the median plication also is involved so that there is a broad flattening or slight depression, without the appearance of a sinus. There is no evidence of a deltidium partly closing the delthyrium.

Strata of uncertain age, but evidently lower Niagaran. Thebes, Illinois.

Rhynchotreta thebesensis occurs in a layer of rather coarse grained crystalline limestone, 3 feet thick, forming the top of the exposure along the river bank a mile north of Thebes. This layer contains *Lichas breviceps-thebesensis*, a form differing from the variety *clintonensis* only in having a pygidium of a slightly more triangular outline than the common Clinton variety. In addition to this, pygidia occur which cannot be distinguished from *Phacops pulchellus*, and others which differ from *Dalmanites werthneri* only in having a terminal spine, 1 mm. in length. *Whitfieldella billingsiana*, Meek and Worthen, is closely related to *Whitfieldella cylindrica*. *Pterinea thebesensis*, Meek and Worthen, may be related to *Pterinea rhomboidea*, Hall. *Atrypa calvina*, Nettleroth, not known from strata as early as the Clinton elsewhere. *Leptæna rhomboidalis*. *Lyellia thebesensis*, forming massive coralla with the walls of neighboring corallites almost in contact with each other, leaving very small interspaces for the *cœnenchyma*. The tabulæ average about 8 or 9 in a length of 5 mm., and the plates in the intermediate spaces are more numerous, but not distinctly vesicular. The diameter of the corallites is slightly more than 1 mm. The walls of the corallites are slightly crenulated, and are slightly striated lengthwise. No septa are visible. See figures 69 A B on plate IV of this Bulletin.

Beneath the coarse grained limestone carrying the preceding fauna there is a layer of clay shale one foot thick, underlaid by a layer of limestone, seven inches thick, containing *Dalmanites danæ*, Meek and Worthen, *Schuchertella subplana*, *Pterinea thebesensis*, Meek and Worthen, and a large form resembling *Meristina maria*. These species of *Dalmanites*, *Orthothetes*, and *Meristina* suggest later age than the Clinton of Ohio, so that the overlying fauna may be regarded as of later than Clinton age, but with a recurrence of some species elsewhere known in the Clinton.

Beneath the *Dalmanites danæ* layer, there are found, in descending order, shale 2 inches thick; limestone, 4 inches thick, wavy at the base; shale, 14 inches thick; a layer of limestone, 8 inches thick. The latter contains *Cyphaspis girardeauensis*, Shumard; *Proetus depressus*, Shumard; *Encrinurus deltoideus*, Shumard; *Acidaspis halli*, Shumard: *Orthis* (*?Schuchertella*) *missouriensis*, Shumard; *Leptæna* (*?Brachyprion*) *mesacosta*, Shumard; *Tentaculites incurvus*, Shumard, and a species of *Cornulites*. This layer evidently contains the fauna described by Shumard from the Cape

Girardeau limestone. This fauna has a Silurian aspect, and here forms the base of the Niagaran section apparently. The fossiliferous layer of limestone here described, and the underlying thin bedded layers, are more or less oolitic and form a section about 33 inches thick a short distance south of the exposures containing the upper faunal layers here described. There is a line of unconformity beneath, indicated by a wavy surface of the underlying rock, along an irregular contact, marked 100 feet south of the main fossil locality by a series of nodular masses occurring at successsively higher elevations in the series.

Rhynchonella (Stegerhynchus) whitii-præcursor, var. nov.

(*Plate III, Figs. 47 A, B, C.*)

Lateral outline broadly ovate, both valves convex, the convexity of the brachial valve being slightly greater. The pedicel valve is distinctly flattened from the point where the plates supporting the teeth terminate on the interior of the shell as far as the point where the downward curvature of the shell at the anterior margin begins. In one specimen, a cast of the interior, with a length of 8 and a width of 9.5 mm., the depth is 7 mm. In most other specimens, possibly less mature, the depth is nearer 5 or 6 mm. Two plications occupy the median fold of the brachial valve rising scarcely a millimeter above the neighboring plications. A single plication occupies the sinus of the pedicel valve. This plication equals in size the plications bordering the sinus.

Interior of the brachial valve marked by plications where the exterior is marked by the grooves between the plications. This results in a median elevation in the interior of the brachial valve. While the other plications on the interior of the valve become indistinct before reaching the crural plates, the median plication is strengthened by a thickening of the shell posteriorly and forms a median elevation which broadens slightly on reaching the anterior margin of the crural plates, apparently filling in the space just beneath these plates. The crural plates present a slightly concave surface approximately parallel to the plane of the valve, and project forward at their inner angles so as to form crural tips. The shell beneath the crural plates is thickened and filled out so that only a narrow space is left between these plates, and this space is occupied by a very narrow, linear septum, representing the cardinal process.

The teeth of the pedicel valve are supported by vertical dental lamellæ, enclosing a cavity of ovate form, distinctly outlined in natural casts of the shell. None of the casts shows a distinct muscular area, but in an indistinct manner this area is represented by the indistinctness of the median plication of the cast, extending to a point 3.7 mm. from the beak. In the cast of this muscular area there is a slight and narrow median depression, and another is shown laterally, suggesting the muscular area of *Rhynchotreta.*

Clinton bed: Clifton, Tennessee.

Compared with *Rhynchonella bidens*, the angulation produced by the fold and sinus along the anterior margin of the valves is much less, and the pedicel valve is less convex. The sinus and fold are relatively broader, and the lateral plications usually number three rather large ones, and one much smaller, the latter sometimes indistinct. It evidently is closely related to *Rhynchonella whitii*, from which it differs chiefly in the smaller size, and the less prominent fold and sinus.

Rhynchonella (Stegerhynchus) neglecta-cliftonensis, var. nov.

(*Plate III, Figs. 48, A, B, C.*)

This shell is unquestionably congeneric with *Rhynchotreta whitii-præcursor.* The brachial valve possesses the same crural plates terminating anteriorly at their inner angles with crural points. These crural plates rest upon the thickened shell beneath but are separated from each other by a space within which the thin longitudinal cardinal process may be seen distinctly. The teeth of the pedicel valve are supported by dental lamellæ, and anterior to the space thus enclosed may be seen the faint traces of the muscular area. The latter is indicated chiefly by the diminished distinctness of the plications which correspond to grooves between the plications of the exterior of the shell.

There are four plications on the median fold, with 3 distinct and 1 indistinct plication on each side, on the brachial valve. In the sinus of the pedicel valve, there are three plications, with 4 distinct and 1 nearly obsolete plications on each side.

Compared with *Rhynchonella neglecta*, from the Clinton group of New York, the shell is larger, broader, less triangular, flatter along the middle parts of the pedicel valve, and the number of lateral plications is smaller.

Clinton bed: Clifton, Tennessee.

According to the preceding observations, *Rhynchonella whitii*, *Rh. neglecta*, and *Rh. indianensis* are congeneric. This group is believed to include also *Rhynchonella bidens*, and *Rhynchonella acinus*. That these shells do not belong to *Camarotoechia* is shown by the thin, lamellar cardinal process. That they do not belong to *Rhynchotrema* is shown by the much smaller, oval muscular area, quite different in form and in the general arrangement of the muscular markings. The nearest relative undoubtedly is *Rhynchotreta cuneata*, to which genus it may belong. To determine this, the delthyrium must be studied. This delthyrium is not preserved in the specimens at hand in such a form that any opinion can be expressed with confidence. The general form of *Rhynchotreta* is very different, but this may be a specific, rather than a generic characteristic. To distinguish the species typified by *Rhynchotreta whitii-præcursor*, from the more typical species of *Rhynchotreta*, possessing an acuminate beak, long broad flattened sides, and a median depression along the posterior parts of the brachial valve, the term *Stegerhynchus* may be employed.

Camarotoechia lindenensis.

(*Plate I, Fig. 13.*)

The generic affinities of this shell can not be determined definitely since the interior is unknown and the tip of the beak is poorly preserved; however, as far as can be determined the beak of the pedicel valve was not perforated. Outline approximately circular; length, 19 mm.; width, 23 mm.; thickness, about 11.5 mm. The specimen may have been thicker originally, but it evidently consisted of a shell of only moderate convexity. Median fold and sinus distinct, rather narrow and of only moderate elevation and depth, the fold rising only 2.5 mm. above the adjacent part of the shell at the anterior margin. Three radiating plications on the median fold, two in the sinus, 8 or 9 on each side. Plications rather sharply angular along the top, crossed by fine close striæ distinctly visible under a lens.

Brownsport bed: near E. Duncan, one and one-half miles east of Linden, Tennessee.

Uncinulus schucherti.

(*Plate I, Fig. 19.*)

Shell resembles *Wilsonia saffordi*, but that part of the ventral valve occupying the fold projects far less beyond the lateral margins of the shell. The dorsal valve is more evenly convex. The anterior face of the shell is not flattened, so that a profile view is less angular. Plications on the mesial fold vary from 4 to 5; of the lateral plications 7 to 10 are distinct, and 2 to 4 indistinct. Largest specimen, 15 mm. long. Globular or moderately elongated. Named in honor of Mr. Charles Schuchert.

Linden bed; above the quarry north of Perryville, Tennessee.

Stephanocrinus tennesseensis.

(*Plate I, Figs. 4 A, B.*)

Closely related to *Stephanocrinus osgoodensis*. Body approximately inversely conical, the sides diverging at angles varying from 50° to 60°; constriction at base usually slight; base usually sharply pointed and triangular in cross-section; some specimens less acute at the base; cavity for reception of stem either very minute or obsolete. Length to base of ambulacral grooves 6.5 to 7.5 mm.; length of interambulacral projections of the body, 2 mm. Surface granulose; the granules are arranged more or less serially in directions corresponding to that of the striæ of the distinctly striated species, and in these directions the granules are usually more or less elongated, but at first sight the granulation is more obvious than is the arrangement of the granules according to some design. In *Stephanocrinus osgoodensis* the surface is traversed by fine closely arranged striæ, the base is less acute, more triangular below, and the cavity for the insertion of the stem is more distinct.

Waldron bed: Iron City, at station; Clifton, three-quarters of a mile above landing, along the river; Swallow Bluff, along upper part of bluff south of landing; along road leading east from New Era, following the Waldron bed outcrop for a considerable distance; all in Tennessee.

Eucalyptocrinus springeri, sp. nov.

(*Plate IV, Fig. 73.*)

This species is closely related to *Eucalyptocrinus elrodi*, from the Waldron bed, at Waldron, Indiana, but differs in the charac-

ter of the surface ornamentation. In a calyx 44 mm. in width the margins rise only 13 mm. above the base. The basal cavity has a width of 7 mm. Surface nearly smooth, but under a lens the plates are seen to be covered by a network of fine lines radiating in an irregular manner in sets from various centers, the lines bending in an irregular vermiculiform manner. Named in honor of Mr. Frank Springer.

Waldron bed: Newsom, Tennessee.

Heliophyllum pegramensis, sp. nov.

(*Plate III, Fig. 58 A, B.*)

Corallum simple, small, short and broad, arising from a very oblique base. Diameter of calyx rarely exceeding 25 mm.; corresponding height, 15 mm., the tip of the base usually extending beyond the vertical projection of the margin of the calyx. Width of calyx in a specimen 25 mm. wide is about 15 mm.; depth of calyx about 7 mm., but the upper margins of the corallum are flattened, as is frequently the case in *Heliophyllum*. Vertical septa, 63 to 68; equal in size at the margin of the calyx, but half way down the calyx the alternate septa are adnate to the primary ones. At the base of the calyx the septa are twisted to the right on approaching the center. Only a slight indication of a septal fossette is found in the calyx, on the convexly curved side of the corallum.

Brownsport bed: Pegram, Tennessee.

Favosites obpyriformis.

(*Plate IV, Fig. 74.*)

Coralla chiefly in nearly globular masses, sometimes inversely pear-shaped, possibly formerly covered with an epitheca toward the base, but no trace of this is found in the specimens at hand. Some specimens attain a height of 12 cm. The corallites vary from 3 to 4 mm. in width, averaging probably nearer 3 mm. Connecting pores large and distant, on the flat walls as well as near the angles of the corallites. Apparently these pores tend to be more frequent near the horizontal diaphragms, so that they tend to be arranged in series at various levels. These diaphragms frequently are distinctly deflected downward at various parts of

the periphery, probably at about those points where the walls of the corallites are pierced by the pores.

Brownsport bed: glade northwest of the home of Charles McClanahan, two miles west of Vice Store, Tennessee.

Chonophyllum (Craterophyllum) vulcanius.

(*Plate I, Fig. 12.*)

Resembles *Chonophyllum canadense*, Billings, as figured by Lambe in *Revision* of the genera and species of Canadian paleozoic corals, 1901. Corallum simple, width 65 mm.; base flat, covered by concentrically wrinkled epitheca. Top fancifully compared with surface of a low volcano. The vertical dimensions at the center are 10 mm.; at 6 mm. from the center of the corallum, 15 mm.; at 17 mm. from the center, 4 mm.; toward the margin the corallum is reduced to a thin sheet. Septa represented at the base of the inner walls of the calyx or crater by about 74 vertical striations which increase in width toward the upper edge of the crater, continuing thence as low broad radiating plications increasing in width as far as the margin of the corallum. A narrow but distinct groove separates these plications along the extracalicular surface. There is no evidence of septa in the extracalicular part of the corallum, nor could any be detected in the central part. The radiating plications are evidently thin horizontally developed sheets, united along their adjacent edges so as to form a continuous expansion, radially grooved, covering the extracalicular surface. Corallum formed by the superaddition of successive expansions. Inner structure between successive expansions entirely vesiculose, composed of convex blister-like plates, irregularly arranged without reference to the radiating grooves traversing the expansions. On close inspection, the location of the blister-like plates may be detected on the upper surface of the expansions. Viewed from beneath, the grooves appear as raised lines, often crossing the concave surfaces of the blister plates. Structure of corallum not preserved at base of calyx or crater; no evidence of tabulæ or of distinct septal plates in this part of the corallum. No distinct concentric striations on the upper, calycular, surface of the corallum. While probably congeneric with *Chonophyllum canadense*, this could not be determined from the specimen at hand.

Brownsport bed: half a mile west of Dr. Evans's, west of Hope creek, Tennessee.

For those chonophylloid corals which have a flat base, upon which the calycular side arises in a manner resembling a low volcanic crater, the designation *Craterophyllum* is proposed. This term includes *Craterophyllum vulcanius* from the Brownsport bed, *Craterophyllum canadense* from the Anticosti Group, and an undescribed species from the Devonian limestone at Louisville, Kentucky.

Diphyphyllum proliferum.

(*Plate I, Figs. 18 A, B, C, D.*)

This species is closely related to *Diphyphyllum rugosum* as figured by Rominger from Louisville, Kentucky, on plate 45, vol. iii, *Geological Survey of Michigan.* Rominger mentions that the gemmation from the calyces is very prolific; from 4 to 6 gemmæ grow at once from an end cup. In the Tennessee specimens 4 gemmæ are common, 6 are very rare. Rominger states that the lateral processes for mutual attachment of the stems are acanthiform and quite numerous; in the Tennessee specimens, however, no lateral processes were noted, and therefore they can hardly be numerous even if present. Moreover, the Tennessee specimens can hardly be said to be annulated by subregularly repeating constrictions, the constrictions hardly being sufficiently pronounced to constitute annulation. In fact, Rominger's figure shows comparatively little strong annulation.

The figure by W. J. Davis, on plate 109 of *Kentucky Fossil Corals*, 1885, appears more typical as regards annulation and the presence of numerous acanthiform processes. The form figured as *Eridophyllum sentum*, on plate 108, appears to have septa extending as superficial carinæ of the tabulæ quite to the center of the calyx. In the Tennessee specimens there are between 40 and 50 septæ, crenulated, of two orders, alternating, the primaries usually extending only a slight distance beyond the margin of the tabulæ, but in one calyx extending as superficial carinæ of the tabula almost to the center. The tabulæ occupy the central area and the septa are confined chiefly to the peripheral cycle; there is no intermediate vertical wall. Septa connected at regular intervals by dissepiments. Diameter of stems between 7 and 11 mm. single specimens occasionally attaining a width of 14 mm. Calyx 3 to 4 mm. deep. Exterior marked by low, often indistinct, longitudinal

ridges corresponding to the spaces between the septa, crossed by fine transverse striæ and constrictions of moderate depth.

Brownsport bed: near home of E. Duncan, one and one-half miles east of Linden; also at the glade southeast of Brownsport Furnace, three miles west of Vice landing, and 8 miles east of Savannah on the Waynesboro road; all in Tennessee.

Alveolites inornatus, sp. nov.

(*Plate III, Fig. 56.*)

Corallum massive, increasing in thickness by the addition of successive layers which are adnate to one another, the later layers often projecting slightly beyond those of earlier origin so as to form an irregularly convex lower side, covered by a very thin epitheca concentrically wrinkled. The upper surface usually comparatively flat. Maximum thickness of one specimen, 32 mm.; width, 80 mm. Four to five apertures in a width of 5 mm;. upper wall of the aperture distinctly convex, its sides resting upon the median parts of the upper walls of the subjacent apertures; lower wall formed by the adjacent parts of the upper walls of the subjacent apertures. No trace of a cycle of denticules at the aperture, nor of longitudinal rows of spinules along the inner surface of the walls forming the aperture; no large marginal pores have been detected. Usually the inner walls of the aperture appear smooth but occasionally there is a longitudinal striation along the median part of the lower wall, and rarely a similar striation along the median part of the upper wall. Anterior outline of upper wall nearly straight or more or less concave. Degree of vertical compression of the aperture variable, the apertures being sometimes comparatively high as in the more typical forms of Alveolites, at other times compressed and transversely slit-like. This form was at first identified with *Alveolites niagarensis*, but the characteristic features of that species cannot be detected.

Brownsport bed: near the home of E. Duncan, one and one-half miles east of Linden, at the mouth of Jacks Branch of Short creek, Tennessee.

Pachypora (Platyaxum) pegramensis, sp. nov.

(*Plate III, Fig. 57.*)

Corallum forming flat, thin fronds, 1 to 3 mm. thick, irregularly lobate, with corallites on both sides. Corallites appearing as nar-

row tubes in the interior of the fronds, approaching the surface at a very oblique angle, rapidly widening at the surface; the upper wall thin, moderately convex, with a convex anterior outline; the lower wall formed by the general surface of the frond, concave for a short distance anterior to the margin of the upper wall; the cavity thus formed at the aperture is filled usually with clay, producing a semilunate border to the anterior edge of the upper wall, very similar to that of *Alveolites platys*. Apertures about 4 in a width of 5 mm.

Associated with these specimens are thin expansions similar to those of *Alveolites platys*, but with corallites equal in size and form of aperture to those of *Platyaxum pegramensis*. The lower surface of these expansions is covered by a wrinkled epitheca. The largest specimen has a width of 11 cm. The free edges of the expansions have a thickness of 1 to 2 mm. The anterior outline of the upper wall of many of the corallites of one specimen is concave or even V-shaped owing to the weathering back of the raised median part of the wall; at some apertures this median part of the upper wall is raised as distinctly as in *Platyaxum platys*. In another specimen the anterior part of the upper wall is only slightly convex, but the anterior outline is distinctly convex. The form of the anterior outline of the upper wall appears to be determined in part by the general curvature of the wall; where the upper wall is very depressed even along the median part the outline is more strongly convex, where the median part is distinctly raised the outline is nearly straight or moderately concave; when the median part is sharply raised the median part of the outline is often distinctly indented, and the adjacent parts project slightly. These flat expansions with a basal epitheca, which we shall call *Alveolites pegramensis* temporarily, are believed to be identical specifically with *Platyaxum pegramensis*. Although no specimens showing the mode of origin of the frondose forms are at hand, it is believed that they originate locally from parts of the flat expansions.

Brownsport bed: bridge two miles west of Pegram, Tennessee.

Pachypora (Platyaxum) platys, sp. nov.

(*Plate I, Figs. 16, A, B, C.*)

Corallum forming flat, thin fronds, 1 to 3 mm. thick, irregularly lobate, with corallites on both sides. The interior of the frond is

dense, the corallites appearing as minute tubes traversing the dense substance at angles very oblique to the surface, gradually approaching the latter. Near the surface the tubes widen rapidly laterally, attaining a width of about half a millimeter at the apertures; they are very oblique to the surface. The apertures are strongly compressed vertically, resulting in an obliquely directed slit; the lower edge of the aperture gradually rises above the surface of the frond, the calyx widening from the tubular portion toward the aperture; near the aperture a cross-section of the lower edge is distinctly convex along the middle and slightly concave toward the sides resulting in a more prominent elevation of the median part of the wall. The outline of the lower margin of the aperture is concave along the median part, often becoming convex at the sides where the sides of the lower edge of the aperture rest upon the general surface of the frond. In well preserved specimens the concavity of the outline of the lower margin of the aperture often is slight, but in worn specimens the median parts have suffered most, and the outline of this part of the aperture is then more strongly concave, or even deeply V-shaped. The upper wall of the aperture is formed by the general surface of the frond. No septal spines or pores or longitudinal ridges were noticed along the upper wall where the upper lower edge of the aperture had been weathered away. The internal structure between the tubular passages of the corallites is unknown; the cell walls apparently are thick walled here but the structure is not clearly defined in the specimens at hand. About 7 apertures in a width of 5 mm.

Brownsport bed: near the home of E. Duncan, on Short creek, one and one-half miles east of Linden, Tennessee.

Among the species referred to *Pachypora*, there is a group characterized by the sharp edge of the thin, strongly flattened, more or less appressed, lower lip, which may be indented with one or two emarginations, or may weather to a deeply indented V-shaped form. Septal spines are wanting. There is no indication of an internal process or septal ridge. This group includes, in addition to *Pachypora platys*, also *Pachypora frondosa*, Nicholson, and probably also *Pachypora fisheri*, Billings. For this group the term *Platyaxum* is here used.

Pachypora (Platyaxum) planostiolata, sp. nov.

(*Plate III, Fig. 55.*)

At the bridge west of Pegram, specimens occur which differ from *Platyaxum platys* chiefly in their mode of growth. They form thin expansions, increasing in thickness by a succession of superimposed layers which often are more or less free toward the margin. The lower side of the corallum and of all of the free parts of the successive expansions is covered by a concentrically wrinkled epitheca. The largest specimen at hand, when complete, must have had a diameter of about 25 cm., and a thickness at the center of at least 15 mm. The free parts of the expansions frequently are less than 2 mm. thick.

The corallites are very oblique to the surface and have very depressed apertures. There is a great variation in the form of the aperture, depending in part on the state of preservation. In most well preserved specimens the lower edge or lip of the aperture is slightly convex and the anterior outline of this wall is distinctly, sometimes strongly convex, producing a lunate aperture. The upper margin of the aperture, formed by the general surface of the corallum, is often distinctly concave for a short distance anterior to the lower edge or lip. A semi-lunate mass or line of clay often appears in the aperture, indicating its form. In some specimens the lower edge or lip of the aperture is distinctly elevated along the median line, the elevation being bordered by narrow, though shallow, depressions on either side. In these cases that part of the anterior margin of the lower lip which is anterior to the grooves often projects slightly farther forward, while the median part is slightly indented, giving a slightly dentate appearance to the anterior outline of this lip. The median parts of the lower lip, when distinctly elevated, often are worn back, as in *Platyaxum platys*. In some worn specimens a distinct longitudinal ridge appears to be present on the interior of the corallite, along the upper wall; in others, it cannot be detected; possibly cross-sections might show it. About 7, sometimes 5, apertures occupy the width of 5 mm.

This species does not appear to be a true *Alveolites*, although specimens congeneric with it appear to be referred usually to that genus. In *Cœnites* the corallites bend abruptly toward the surface meeting the latter almost at right angles, the walls being thickened abruptly near the surface. These features are not noticed in the

specimens here described. It is believed that further study will prove this species to be congeneric with *Platyaxum platys* although at present the different forms of growth must distinguish them.

Brownsport bed: railroad bridge two miles west of Pegram, Tennessee.

Caryomanon patei, sp. nov.

(*Plate I, Fig. 15.*)

Sponge distinctly flattened on what is assumed to be the lower side. Upper side strongly convex, rounding into the base. Upper surface marked by rather shallow channels which tend to occur in pairs or in groups of three, but this grouping is not very evident. Some of the deeper channels give a slight lobation to the lower parts of the side of the sponge, but this lobation also is very indistinct. The oscula, almost a millimeter in diameter open in these radiating channels, especially along the upper part of their length. The channels become indistinct about 7 to 9 mm. from the center of the top of the sponge. The largest specimen found is 43 mm. in width, and 21 mm. in height.

Brownsport bed: near the A. B. Gant place, northeast of Martins Mills, in Tennessee. Species named in honor of Mr. W. F. Pate, whose collections have contributed greatly of our knowledge of the Silurian formations of western Tennessee.

PLATE I.

FIG. 1. Pentamerella manniensis. *A*, *D*, pedicel valves. *B*, *C*, brachial valves. Northwest of Riverside, Tennessee. Clinton bed.

FIG. 2. Stricklandinia dichotoma. *A*, Riverside. *B*, Iron City, Tennessee. Clinton bed.

FIG. 3. Hyolithus newsomensis. *A*, dorsal side. *B*, ventral side. Newsom, Tennessee. Waldron bed.

FIG. 4. Stephanocrinus tennesseensis. *A*, *B*, Iron City, Tennessee. Waldron bed.

FIG. 5. Plectambonites tennesseensis. *A*, *B*, *C*, pedicel valves. *D*, *E*, brachial valves. Iron City, Tennessee.

FIG. 6. Anoplothecas affordi. Pedicel valve. Gant Place. Northeast of Martins Mills, Tennessee. Brownsport bed.

FIG. 7. Homœospira pisum. Brachial valve. Bath Springs, Tennessee. Brownsport bed.

FIG. 8. Homœospira beecheri. *A*, pedicel valve. *B*, brachial valve. Brownsport furnace, Tennessee. Brownsport bed.

FIG. 9. Homœospira schucherti-elongata. *A*, pedicel valve. *B*, brachial valve. Bath Springs, Tennessee. Brownsport bed.

FIG. 10. Homœospira schucherti. *A*, pedicel valve, *B*, brachial valve. Brownsport Furnace, Tennessee. Brownsport bed.

FIG. 11. Atrypa reticularis-newsomensis. *A*, *B*, pedicel valves. Newsom, Tennessee. Waldron bed.

FIG. 12. Chonophyllum (Craterophyllum) vulcanius. West of Dr. Evans, west of Hope creek, Lewis county, Tennessee. Brownsport bed.

FIG. 13. Camarotoechia lindenensis. East of Linden, Tennessee. Brownsport bed.

FIG. 14. Diaphorostoma brownsportensis. Brownsport furnace, Tennessee. Brownsport bed.

FIG. 15. Caryomanon patei, nov. sp. Gant Place, two miles northeast of Martins Mills, Tennessee. Brownsport bed.

FIG. 16. Pachypora (Platyaxum) platys. *A*, three fragments placed arbitrarily so as to suggest lobation of the frond. *B*, *C*, basal fragments referred to this species. East of Linden, Tennessee. Brownsport bed.

FIG. 17. Rhipidomella saffordi. *A*, *B*, brachial valves. *C*, pedicel valve. Gant stables, northeast of Martins Mills, Tennessee. Brownsport bed.

FIG. 18. Diphyphyllum proliferum. *A*, *B*, side views of budding stems. *C* top view of budding stem. *D*, calycular view. East of Linden, Tennessee., Brownsport bed.

FIG. 19. Uncinulus schucherti. View from side of brachial valve. Perryville, Tennessee. Linden bed.

A. F. FOERSTE

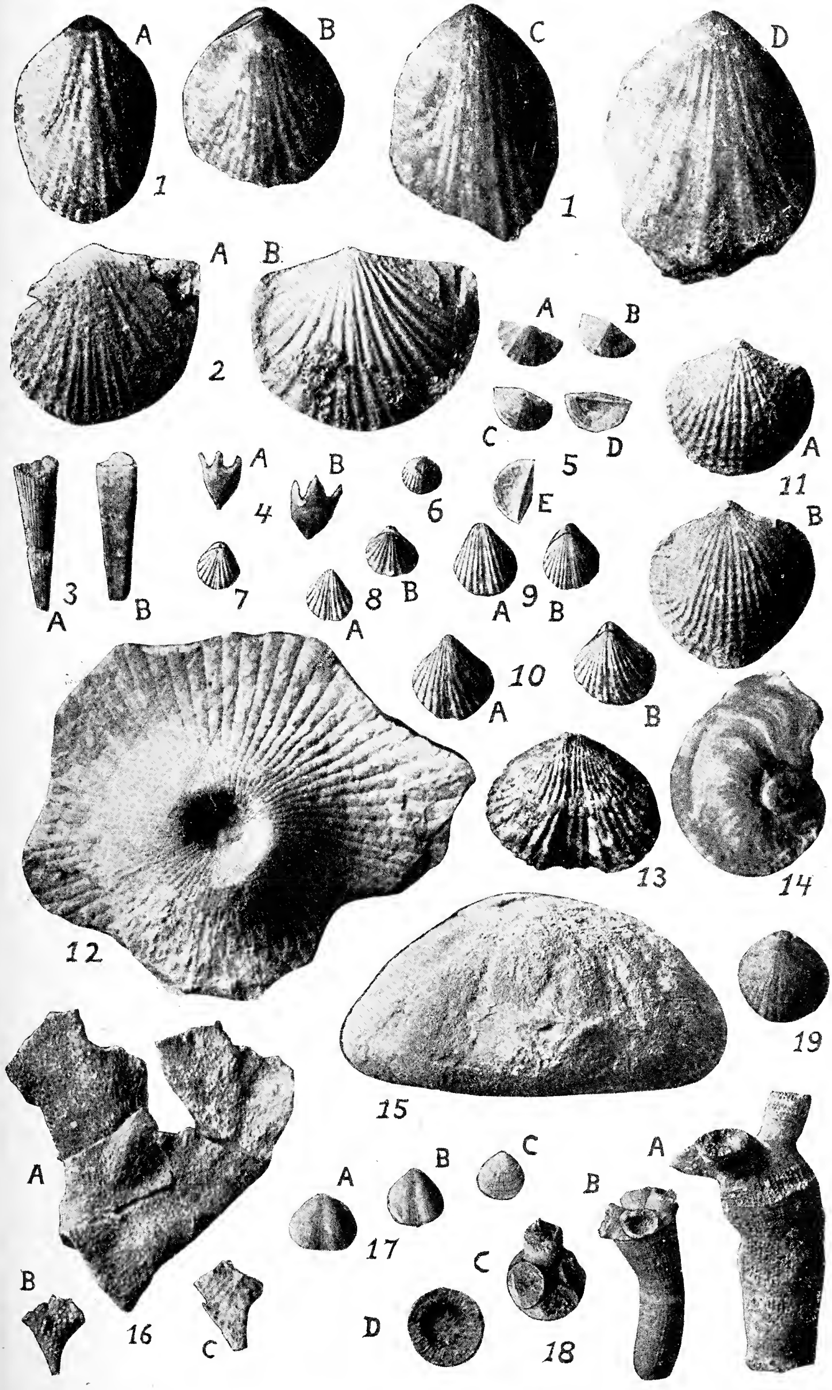
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PLATE II.

Fig. 20. Strophonella tenuistriata. *A*, pedicel valve, from Cerro Gordo. *B*, brachial valve, from New Era. Both from Tennessee. Brownsport bed.

Fig. 21. Strophonella dixoni. Brachial valve. Dixon Spring, Tennessee. Brownsport bed.

Fig. 22. Strophonella ganti. Brachial valve. Gant place, northeast of Martins Mills, Tennessee. At base of Gant division of Brownsport bed.

Fig. 23. Strophonella prolongata. *A*, *B*, brachial valves. Brownsport Furnace, Tennessee. Brownsport bed.

Fig. 24. Strophonella rœmeri. Brachial valve. Brownsport Furnace. Brownsport bed.

Fig. 25. Strophonella laxiplicata. *A*, pedicel valve. *B*, Fragment of pedicel valve, with striæ more prominent than usual at the beak. Brownsport Furnace. Brownsport bed.

Fig. 26. Strophonella semifasciata-Brownsportensis. Fragment of brachial valve. Brownsport, Tennessee. Brownsport bed.

Fig. 27. Schuchertella rœmeri. *A*, *C*, brachial valves. *B*, ventral valve. Dixon Spring, Tennessee. Brownsport bed.

Fig. 28. Rhipidomella lenticularis. *A*, brachial valve. *B*, pedicel valve. Brownsport Furnace, Tennessee. Brownsport bed.

Fig. 29. Meristina maria-rœmeri. *A*, brachial valve. *B*, Anterior view. Glenkirk, Tennessee. Brownsport bed.

Fig. 30. Spirifer geronticus. *A*, cardinal view. *B*, Ventral valve, fragment. Dixon Spring, Tennessee. Brownsport bed.

Fig. 31. Reticularia pegramensis. *A*, pedicel valve. *B*, brachial valve. Pegram, Tennessee. Brownsport bed.

Fig. 32. Cyrtia cliftonensis. Pedicel valve. Clifton, Tennessee. Brownsport bed.

Fig. 33. Spirifer swallowensis. Brachial valve, photographed in an inverted position in order to indicate the concentric striæ better. Only two plications are shown here, one of which corresponds to the median fold; the other is the lateral plication. Swallow bluff, Tennessee. Waldron bed.

Fig. 34. Atrypa arctostriata. *A*, pedicel valve. *B*, brachial valve. Brownsport Furnace. Brownsport bed.

Fig. 35. Conchidium lindenensis. Pedicel valves. Coon creek, east of Linden, Tennessee. Brownsport bed.

Fig. 36. Conchidium legœnsis. Northeast of Lego, Tennessee. Brownsport bed.

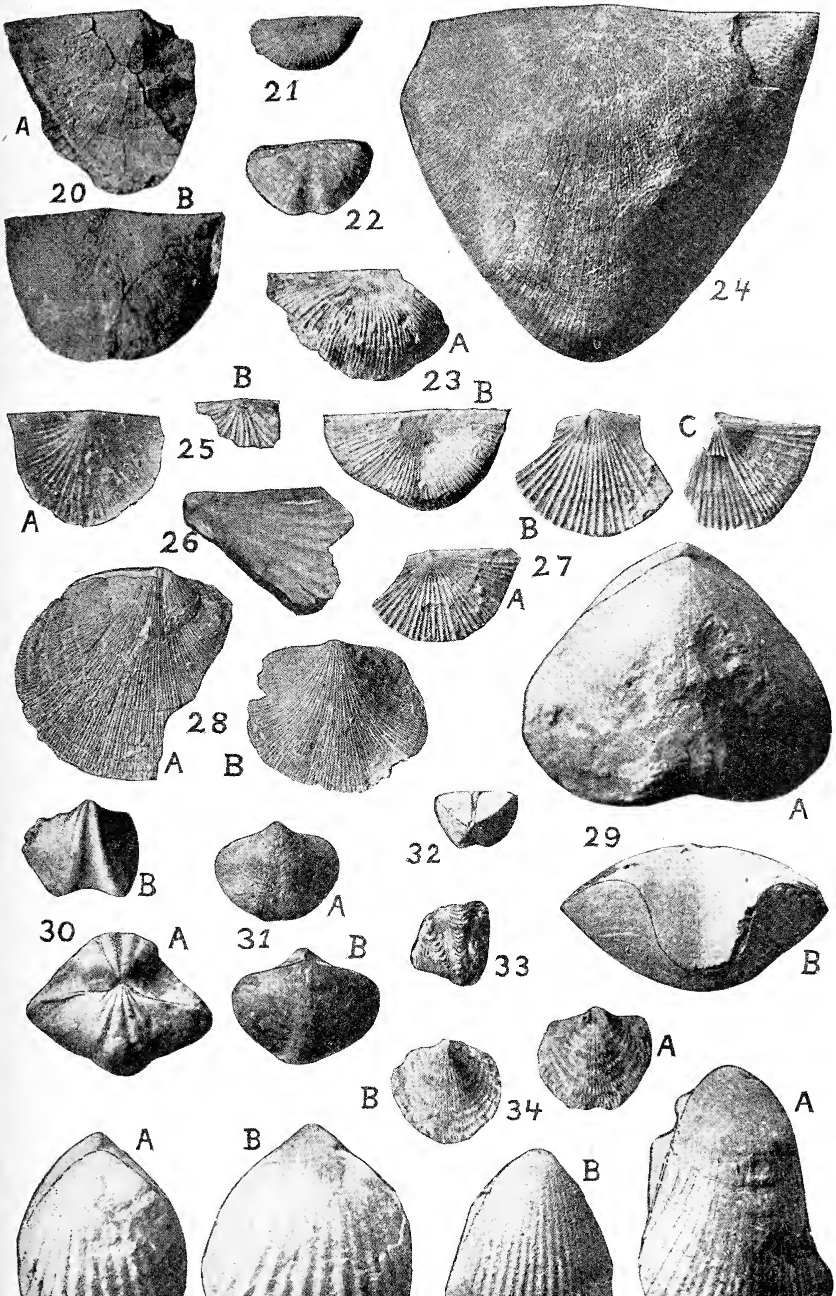
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PLATE III.

Fig. 37. Cyrtoceras cinctutus. *A*, lateral view. *B*, dorsal view. Clifton, Tennessee. Osgood bed.

Fig. 38. Hyolithus cliftonensis. *A*, Ventral view. *B*, Dorsal view. Clifton, Tennessee, Osgood bed.

Fig. 39. Triplecia (Cliftonia) tenax. Clifton, Tennessee. Osgood bed.

Fig. 40. Platyceras pronum. View of upper side. Clifton, Tennessee. Osgood bed.

Fig. 41. Diaphorostoma cliftonensis. *A*, side view. *B*, view showing aperture. Clifton, Tennessee. Osgood bed.

Fig. 42. Triplecia (Cliftonia) striata. *A*, brachial valve. *B*, pedicel valve. Clifton, Tennessee. Clinton bed.

Fig. 43. Orthis flabellites. Brachial valve. New Marion, Indiana. Osgood bed.

Fig. 44. Orthis interplicata. Brachial valve. New Marion, Indiana. Osgood bed.

Fig. 45. Hebertella (Schizonema) fissistriata. *A*, brachial valve. *B*, interior of brachial valve. New Marion, Indiana, Osgood bed.

Fig. 46. Rhynchotreta simplex. *A*, pedicel valve. *B*, brachial valve. Clifton, Tennessee. Clinton bed.

Fig. 47. Rhynchonella (Stegerhynchus) whitii-præcursor. *A*, *B*, brachial valves. *C*, pedicel valve. Clifton, Tennessee. Clinton bed.

Fig. 48. Rhynchonella (Stegerhynchus) neglecta-cliftonensis. *A*, brachial valve. *B*, pedicel valve. *C*, anterior view. Clifton, Tennessee. Clinton bed.

Fig. 49. Wilsonia saffordi. Lateral view, with the pedicel valve on the right. Brownsport Furnace, Tennessee. Brownsport bed.

Fig. 50. Uncinulus schucherti. Lateral view. Ferryville, Tennessee. Linden bed.

Fig. 51 A, B. Gypidula simplex. *A*, pedicel valve. *B*, view from side of brachial valve. Newsom, Tennessee. Waldron bed.

Fig. 51 C. Gypidula rœmeri. Pedicel valve. Newsom, Tennessee. Waldron bed.

Fig. 52. Chonostrophia lindenensis. Pedicel valve. Pyburn bluff, Tennessee. Linden bed.

Fig. 53. Hebertella celsa. *A*, Interior of brachial valve. *B*, view from side of pedicel valve. Perryville, Tennessee. Linden bed.

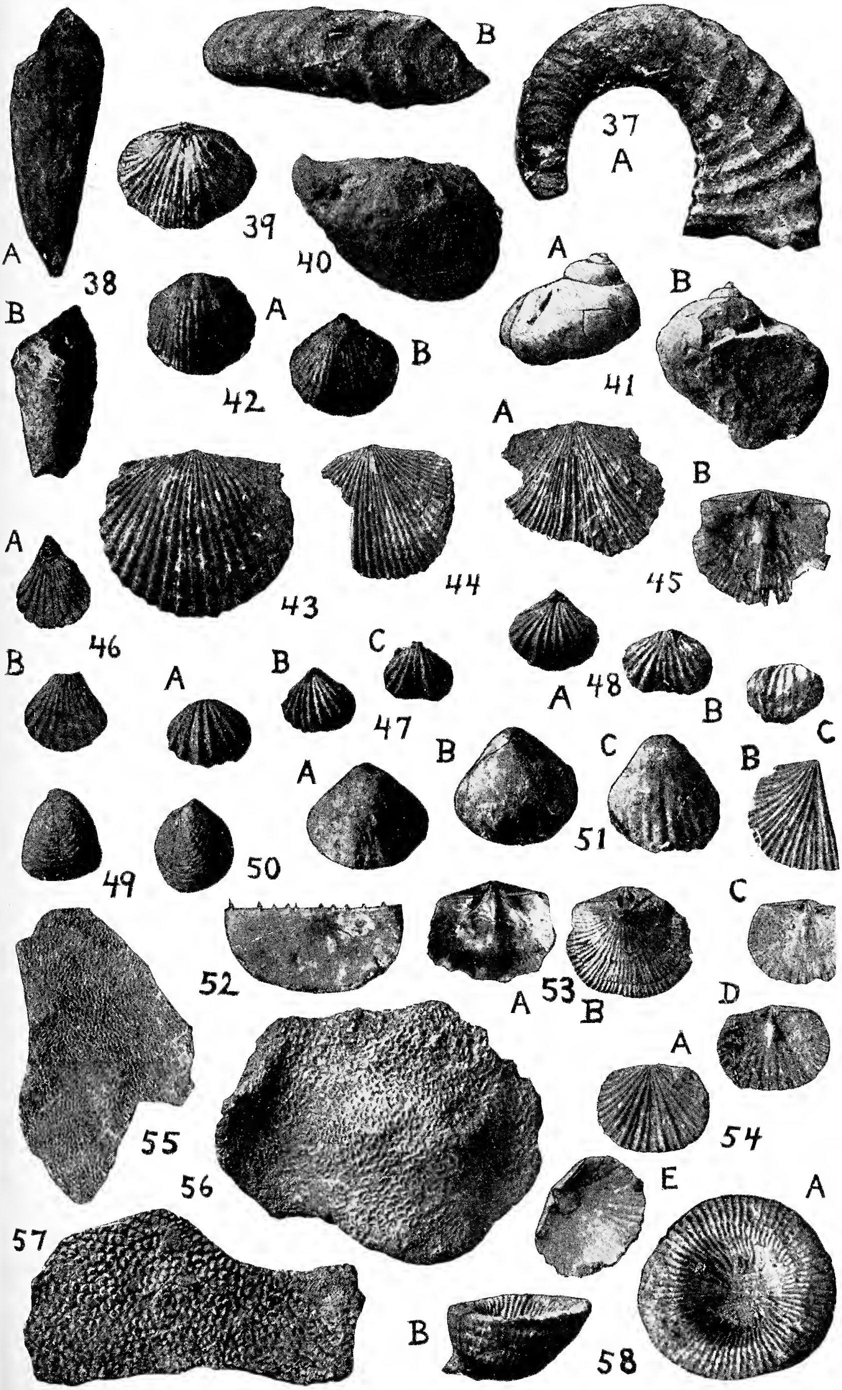
Fig. 54. Hebertella (Schizonema) fissiplica. *A*, *B*, brachial valves. *C*, *D*, interiors of brachial valves. *E*, interior of pedicel valve. Dixon Spring, Tennessee. Brownsport bed.

Fig. 55. Pachypora (Platyaxum ?) planostiolata. Upper surface, showing the apertures of the corallites. Pegram, Tennessee. Brownsport bed.

Fig. 56. Alveolites inornatus. Upper surface. A mile and a half east of Linden. Tennessee. Brownsport, bed.

Fig. 57. Pachypora (Platyaxum) pegramensis. Part of a frond, with the broken edge along the lower side of the figure. Pegram, Tennessee. Brownsport bed.

Fig. 58. Heliophyllum pegramensis. *A*, Calyx. *B*, side view. Pegram, Tennessee. Brownsport bed.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58 A
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PLATE IV.

FIG. 59. Pterinea newsomensis. *A*, Left valve. *B*, right valve, with concentric striations on the posterior wing. Newsom, Tennessee. Waldron bed.

FIG. 60. Pterinea nervata. Left valve with outline restored after comparison with Pterinea newsomensis. Between the conspicuous radiating striæ there are 2 to 3 much finer striations, not readily seen except under a lens. Newsom, Tennessee. Waldron bed.

FIG. 61. Pterinea brisa. Left valve. Newsom, Tennessee. Waldron bed.

FIG. 62. Rhombopteria (Newsomella) ulrichi. *A*, right valve, with cross-striations. *B*, left valve, with only concentric striæ, more or less lamellose. Newsom, Tennessee. Waldron bed.

FIG. 63. Rhombopteria (Newsomella) revoluta-divaricata. *A*, right valve, with posterior wing restored. *B*, left side. *C*, right valve, apparently representing a shell shorter in length but greater in height than those figured by *A* and *B*. Newsom, Tennessee. Waldron bed.

FIG. 64. Orthostrophia newsomensis. Pedicel valve, with small deep muscular area and strong vascular markings. Newsom, Tennessee. Waldron bed. Glade southwest of Dixon Spring, Tennessee. Brownsport bed.

FIG. 65. Orthostrophia dixoni. Pedicel valve, with small deep muscular area. Glade southwest of Dixon Spring, Tennessee. Brownsport bed.

FIG. 66. Rhynchotreta thebesensis. *A*, Brachial valve. *B*, Lateral outline of a thin shell. *C*, Lateral view of a more obese specimen, illuminated from the lower right hand side so as to show the flattened sides toward the beak. Beak of pedicel valve restored. About a mile north of Thebes, Illinois. In the lower part of the Silurian, about 3 feet above the Cape Girardeau limestone.

FIG. 67. Stropheodonta (Brachyprion) newsomensis. Pedicel valve. Newsom, Tennessee. Waldron bed.

FIG. 68. Scendium bassleri. *A*, Brachial valve. *B*, lateral outline. Newsom, Tennessee. Waldson bed.

FIG. 69. Lyellia thebesensis. Two specimens. About a mile north of Thebes, Illinois, 3 feet above the Cape Girardeau limestone. Silurian.

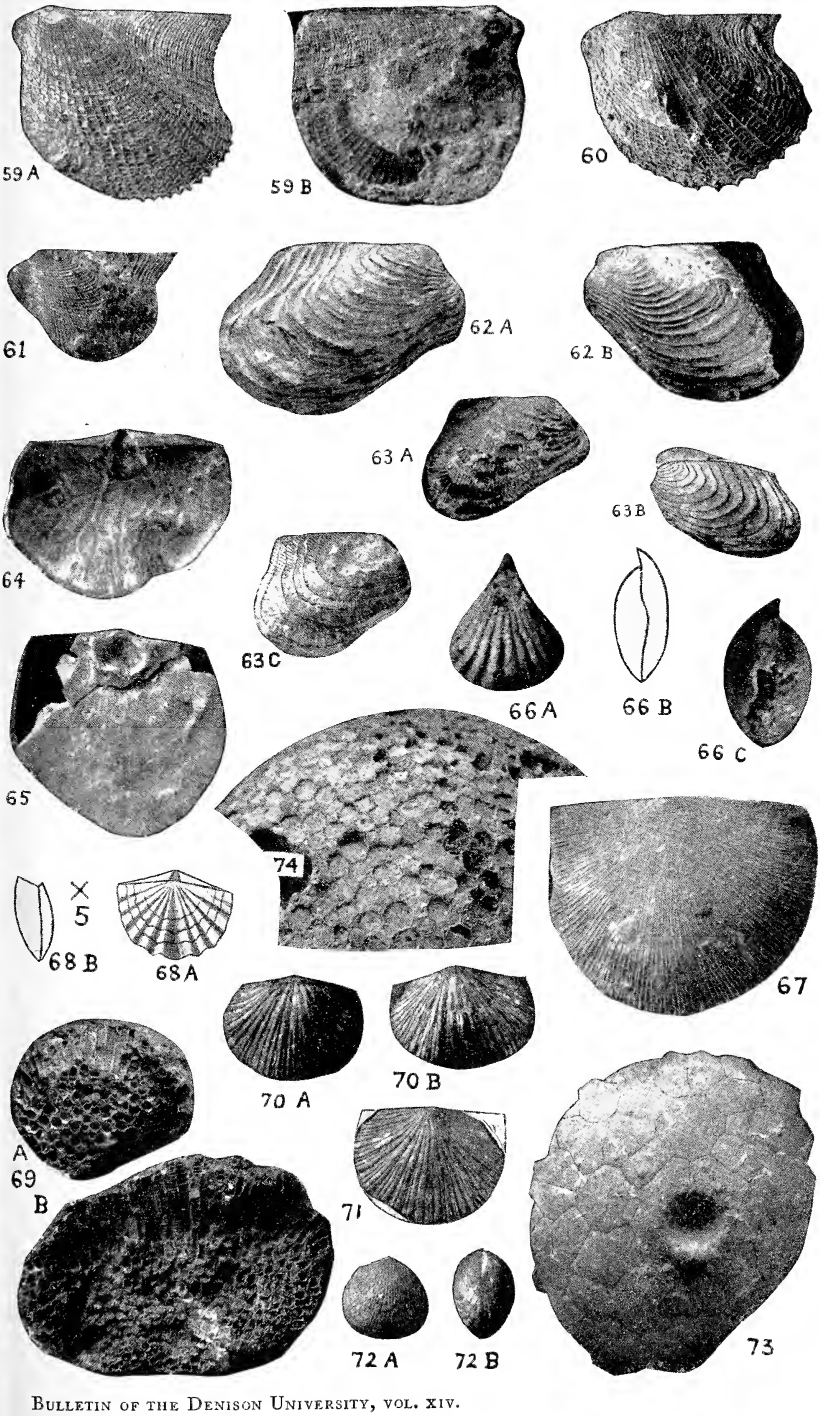
FIG. 70. Triplecia (Cliftonia) tenax. *A*, Brachial valve. *B*, Pedicel valve. Clifton, Tennessee. Osgood bed.

FIG. 71. Hebertella (Schizonema) fasciata. *A*, Pedicel valve. New Marion, Indiana. Osgood bed.

FIG. 72. Rhipidomella newsomensis. *A*, Brachial valve. *B*, Lateral view. Newsom, Tennessee. Waldron bed.

FIG. 73. Eucalyptocrinus springeri. Ornamentation too minute to be seen readily without a lens. Newsom, Tennessee. Waldron bed.

FIG. 74. Favosites obpyriformis. Part of a globular corallum 6 cm. in width. Glade 2 miles west of Vice store, Tennessee. Brownsport bed.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I. THE DETERMINATION OF TIN IN BABBITT AND OTHER ALLOYS.[1]

J. A. Baker.

Mr. W. H. Low published a method for the "Determination of Antimony and Tin in Babbitt, Type Metal or other Alloys," which appeared in the *Journal of the American Chemical Society*, vol. xxix, no. 1, 1907. When it became necessary to make an analysis of a bronze containing copper, lead, tin, and zinc, Mr. Low's method gave promise of a rapid means of estimating the tin. It was, therefore, thoroughly tested.

Mr. Low's method for tin is as follows: Decompose the alloy with nitric acid and expel the latter by boiling with sulphuric acid till fumes of the anhydride come off thickly, add tartaric acid and potassium sulphate, heat the melt till the carbon is oxidized, cool and dilute with water. Transfer to a 500 cc. flask, add about one gram of powdered antimony, and hydrochloric acid to the extent of one-fifth the volume of the solution. Connect the flask with an apparatus capable of furnishing carbon dioxide, and while the gas is passing, heat the liquid to the boiling point, and boil for about three minutes, then cool while the current of gas is still passing.

This process leaves the tin in a proper state of oxidation to titrate with a standard iodine solution. Furthermore, according to Mr. Low, no amount of lead will interfere and "theoretically *no amount of copper* should interfere, while small amounts are known to give no trouble." Attention was attracted to the article by this last statement, for evidently the process separates neither the copper nor the lead, the former being present in solution and the latter for the most part as solid lead sulphate.

In practice in this laboratory, after bringing the solution up to the proper condition for titration according to the above directions, a few cubic centimeters of good starch solution were added, and

[1] These studies were undertaken at the suggestion of Prof. A. M. Brumback as a partial requirement for the Master's Degree.

then a few drops of standard iodine solution were run in. At the first drop a heavy, dirty-white precipitate formed. It was evident from the nature of the precipitate and the substances in solution that cuprous iodide, stained with free iodine, was being precipitated. However, several titrations were made, in the hope that the interfering action of the copper would be perfectly regular, and that a correction could be made after the amount of copper present had been determined. The addition of iodine was therefore continued till the characteristic blue coloration indicated that the end point had been attained. Care was taken to stir the solution thoroughly after each addition. The heavy precipitate present obscured the end point to some extent, but it was sufficiently well noted each time.

Three different portions of the alloy were taken, and the following results were calculated to a weight of 4 grams of the alloy. One portion required 175 cc. of the standard iodine solution, another required 133 cc., and the other required 159 cc. It was manifest that the reaction was altogether too irregular to justify any confidence in it.

The following method was finally used in the determination of the metals present in the alloy. Take portions of two or three grams each and cover with nitric acid (1:1). Action takes place at once without heating, and soon the alloy is entirely decomposed. Expel nitric fumes and add about 10 cc. of concentrated sulphuric acid. Heat till white fumes come off quickly. Cool, add 50 cc. of water, filter and wash. The lead in the precipitate may be estimated gravimetrically or volumetrically. The filtrate contains the copper, tin and zinc.

To the filtrate add enough water to make its volume up to 150 cc. Add 25 cc. of sulphuric acid. Place clean aluminum foil in the liquid and bring up to a boil. Boiling is continued till all the copper is precipitated in the metallic form. Separate the metallic copper by decantation or filtration, wash and weigh as metallic copper, after drying; or dissolve and estimate volumetrically. The copper is now entirely separated from the tin, the latter remaining in the filtrate along with the zinc which does not interfere with the estimation of the tin by iodine. The tin is now reduced by metallic antimony in a current of carbon dioxide as directed by Mr. Low, and titrated with the iodine solution.

The iodine solution produces, now, no precipitate, but the oxida-

tion goes on in a perfectly clear solution and the end point is sharply defined and unmistakable. An analysis gave the following results:

Copper	62.33
Lead	1.66
Tin	.53
Zinc	35.29
	99.81

The amounts of iodine solution required for the estimation of the tin in two samples calculated to 4 grams per sample, were as follows:

Modified method, 6.82 cc. 6.88 cc., as compared with Mr. Low's method, 133.cc., 175.cc. and 159.cc.

II. BABBITT ANALYSIS BY THE METHOD OF W. H. LOW.

The method followed in this work was that of Mr. W. H. Low, published in the *Journal of the American Chemical Society* for January 1907, with some slight modifications that seemed to be demanded by the nature of the work. It was in connection with this work that the application of the method to alloys containing large amounts of copper, was tried. The criticism of the method for such alloys appears elsewhere in these pages.

Below appears a detailed statement of what was done in applying the method. Standard solutions of ammonium molybdate, potassium permanganate, iodine and sodium thiosulphate were prepared. These were made and standardized as appears below.

I. *Ammonium molybdate.* About 9 grams of the dry salt were dissolved in each liter of water. This solution was then standardized by titrating it against thoroughly dried, pure lead sulphate. The latter was dissolved in ammonium acetate, diluted to 250 cc., acidified with acetic acid, heated to boiling and titrated, using tannin as an indicator. The tannin solution was made by dissolving tannin in about 300 parts of water. The value of the molybdate solution was calculated as follows:

Weight of $PbSO_4$ taken	= .xxxx (*a*)
Weight of lead in (*a*) = (*a*) $\times$ .68292	= .xxxx (*b*)
Volume of molybdate solution used	= .xxxx (*c*)
1 cc. of molybdate = (*b*) $\div$ (*c*)	= .xxxxx g. Pb.

II. *Potassium permanganate.* The pure salt was dissolved in water, about 4 grams being taken for each liter of water. This was standardized according to the two following methods:

a. With metallic iron. Thin annealed wire, containing 99.6 per cent of pure iron was dissolved in dilute sulphuric acid, in an Erlenmeyer flask fitted with a Bunsen valve. Heat was usually applied to hasten solution. When solution was complete the flask and contents were cooled without removing the stopper, by holding under a stream of water. The stopper was then removed, the liquid was diluted, if necessary, with recently boiled, distilled water, and the iron was titrated with the permanganate solution to a faint pink color. The calculation for the iron value of the permanganate was made as follows:

Weight of iron wire taken	= .xxxx (*a*)
Weight of iron in (*a*) = (*a*) × .996	= .xxxx (*b*)
Volume of permanganate used	= .xxxx (*c*)
1 cc. of permanganate = (*b*) ÷ (*c*)	= .xxxxx g. Fe

b. With ferrous ammonium sulphate. Weighed portions of the salt were dissolved in acidulated water in a flask into which had been previously put a little sodium carbonate. The water was acidulated with sulphuric acid. As soon as solution was complete the iron was titrated with the permanganate solution, and the value of the latter calculated as follows:

Weight of $(NH_4)_2Fe(SO_4)_2.6H_2O$	= .xxxx (*a*)
Weight of iron present = (*a*) × .14251	= .xxxx (*b*)
Volume of permanganate used	= .xxxx (*c*)
1 cc. of permanganate = (*b*) ÷ (*c*)	= .xxxxx g. Fe

Since the purpose of the permanganate solution in the work undertaken was to determine antimony, the iron value as found above was calculated to the antimony value as follows:

The equations for the action of permanganate upon iron compounds and upon antimony compounds are these:

$$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 = 5Fe_2(SO_4)_3 + K_2SO_4 + 2MnSO_4 + 8H_2O$$
$$2KMnO_4 + 5SbCl_3 + 16HCl = 2MnCl_2 + 5SbCl_5 + 2KCl + 8H_2O$$

It is apparent, then, that 10 atoms of iron are equivalent to 5 atoms of antimony in reducing $KMnO_4$. Hence the following proportion will give the antimony value of the permanganate solution,

letting d represent the iron value of the solution and x, the antimony value:

$$55.9 \times 10 : 120.1 \times 5 :: d : x.$$

Whence

$$x = d \times 1.075.$$

III. *Sodium thiosulphate.* Make the solution with about 19 grams of the crystallized salt per liter. Such a solution was standardized against copper sulphate, the copper content of which had been very accurately ascertained in connection with other laboratory work. The weighed amounts of the copper sulphate were dissolved in about 200 cc. of water. To this was added 5 cc. of ammonium acetate solution and 5 cc. of dilute acetic acid. Then were added about ten times the copper weight of potassium iodide crystals and the mixture stirred. The liberated iodine was titrated with the thiosulphate solution nearly to the end, when a few cubic centimeters of clear starch solution were added and the titration finished. This standard solution was used only for the purpose of standardizing the iodine solution and titrating back against the iodine solution during the estimations. The iodine value of the thiosulphate solution was calculated as follows from the reaction equation:

$$2CuSO_4 + 4KI = 2I + Cu_2I_2 + 2K_2SO_4$$

Weight of copper sulphate taken = .xxxx (a)

Percentage of copper present in the sulphate = .xxxx (b)

Weight of pure copper present = (a) $\times$ (b) = .xxxx (c)

Weight iodine equivalent to copper = (c) $\times \left(\frac{126.97}{63.6}\right)$ = .xxxx (d)

Volume $Na_2S_2O_3$ used = .xxxx (e)

1 cc. thiosulphate = (d) $\div$ (e) = .xxxxx g. I.

IV. *Iodine.* About 18 grams of pure potassium iodide were dissolved in 250 cc. of water and 13 grams of iodine were dissolved in the resulting solution. When solution was complete the whole was diluted to a liter. This iodine solution was titrated against measured volumes of the standard thiosulphate solution using a clear solution of starch as an indicator in just the way described above. The standard values were calculated as below:

1 cc. of thiosulphate in grams of iodine (as above) = .xxxx (a)

1 cc. of thiosulphate in cubic centimeters of I sol. = .xxxx (b)

1 cc. of the iodine solution in grams of iodine($a \div b$) = .xxxx (c)

Since this iodine solution was used in the estimation of tin, its tin value was calculated as follows from the reaction equation:

$$SnCl_2 + 2I + 2HCl = SnCl_4 + 2HI.$$

Therefore

$$Sn : 2I :: x : c$$

or

$$119 : 253.94 :: x : c$$

where c is the weight of iodine in 1 cc. of the iodine solution, and x is the weight of the tin equivalent to one cubic centimeter of the iodine solution. Then $x = (c) \times .4686$.

METHODS OF ANALYSIS.

I. *For the estimation of lead.* Samples of about 0.5 gram each were used. The alloy was in the form of fine drillings, often flattened by hammering. The samples were digested in dilute nitric acid (sp. g. = 1.20) on the water-bath for about 2 hours. The decomposition seemed to be so effected by this method of treatment that better results were obtained than by hurried decomposition at higher temperatures. When the decomposition seemed to be complete, the samples were removed from the water bath and quickly evaporated till about 5 cc. of liquid remained, then they were diluted with 100 cc. of water, boiled up, filtered and washed repeatedly with hot water. The filtrate was diluted to about 250 cc. with water (if the volume together with the washings was less than that), heated to 50° to 60° and the lead was precipitated by adding 10 cc. of sulphuric acid (1 : 1). The precipitate was allowed to settle and was then filtered and washed, first with very dilute sulphuric acid and then two or three times with pure cold water. The precipitate, without separating from the filter paper, was placed in a flask and dissolved with 10 to 15 cc. of strong ammonium acetate solution. The volume was then made up to 250 cc., heated to incipient boiling and titrated with the standard molybdate solution, using tannin as an indicator. The results are recorded at the end of this paper.

II. *For the estimation of antimony and tin.* The method here described is based upon that published by Mr. Low, in the article heretofore referred to. The finely divided alloy was weighed out in samples of about 1 gram each. They were placed in an Erlen-

meyer flask and were treated with 15 or 20 cc. of concentrated sulphuric acid and 2 to 4 grams of potassium sulphate. Heat was applied till the melt was perfectly white, but care was taken not to drive off all the sulphuric acid. The samples were then cooled and diluted with 50 cc. of water and 10 to 15 cc. of strong hydrochloric acid added. Heat was applied till all possible had passed into solution. The flask was cooled and the contents rinsed into a 600 cc. beaker and diluted to 400 or 500 cubic centimeters and then titrated with the permanganate solution. The results of the estimation will be found at the end of this paper.

The method just described involves a radical departure from Mr. Low's method. Mr. Low advocates the use of hydrochloric acid solution for the titration of the antimony in which the content of HCl is about 10 per cent the volume of the solution. Attempts to use such a concentration ended in utter failure at laboratory temperatures, 20° to 22°. Very shortly after the permanganate was added the solution turned yellow, evolved the odor of chlorine and threw down a brown precipitate, all of which showed that the permanganate was being decomposed by the hydrochloric acid present. The decomposition was so energetic that absolutely no end point could be observed. The concentration recommended by Mr. Low is somewhat greater than that recommended by Fresenius and Sutton, but these authors also recommend the addition of Magnesium sulphate or other similar agent. In these experiments the volume of the acid was reduced to the proportions stated above.

The solution in which the antimony had been estimated was poured into a round bottomed flask, was rinsed out with 50 cc. of strong HCl, the rinsings being added to the contents of the flask. The solution at this point was made to contain one-fifth its volume of strong hydrochloric acid. There was then added about one gram of finely powdered antimony. The flask was shaken well and the contents digested on a water-bath till the volume was about 300 cc. The flask was next connected with an apparatus for delivering a rapid stream of CO_2, connection being made so that bubbles of the gas passed rapidly through the solution. While the gas was passing, the flask was heated to boiling and maintained at the temperature for about fifteen minutes. This was long enough to secure the reduction of all the tin. While

the gas was still passing the flask and contents were cooled by pouring cold water over the former. The flask was then disconnected from the apparatus, 5 cc. of good starch solution were added to its contents and titration was effected by means of the standard iodine solution. The thiosulphate solution was used to tritrate back if the end point was passed. The results for tin are here tabulated:

Analytical Results.

	Pb.	*Sn.*	*Sb.*	*Total.*
Magnolia Metal	78.92	5.52	15.21	99.65
	79.34	5.50	15.01	99.85
	78.69	5.93	15.35	99.97
Eagle A	82.30	2.24	15.24	99.78
	82.42	2.13	15.14	99.69
	82.81	2.07	14.73	99.61
Frictionless	84.61	3.08	12.22	99.91
	84.72	3.07	12.11	99.90
	84.27	3.23	12.27	99.77
Mystic	82.40	4.53	13.23	100.16
	82.47	4.40	12.92	99.79
	82.82	4.03	13.13	99.98

III. BABBITT ANALYSIS BY THE METHOD OF H. YOCKEY.

Yockey's method was published in the *Journal of the American Chemical Society* for May, 1906. Below is the method of Yockey as modified. The methods for lead and tin are just as he describes them, but it was found impossible to secure results for antimony by his method, hence the method described below for antimony was substituted. This method proved to be much shorter than Low's method, and the results are quite as satisfactory.

Weigh into a 250 cc. beaker 0.5 grams of the finely divided alloy. Add 20 cc. of nitric acid (sp. g. 1.2) and put on the water-bath. When the alloy is completely decomposed (one or two hours) put in an air bath and evaporate to complete dryness. Bake at 120° for one hour. Remove from the oven, cool, moisten with one cubic centimeter of nitric acid, add 50 cc. of water and boil vigorously for five minutes. Filter off the mixed oxides of tin and antimony, wash with hot water, dry, ignite in a porcelain cru-

cible and add a few drops of strong nitric acid to oxidize any metal reduced while burning the filter paper. Weigh as Sb_2O_4 and SnO_2. Dilute the filtrate from the above to 200 cc., add 10 cc. of ammonium acetate and 5 cc. of dilute acetic acid, heat to incipient boiling and titrate with ammonium molybdate in the usual way.

For antimony weigh out from 0.6 to 0.8 gram of the finely divided alloy into a 500 cc. beaker, add 50 cc. of strong hydrochloric acid, and allow to stand for some time. (In practice it was found to be a good plan to let the alloy stand in cold HCl over night. The disintegration into a fine powder seemed to be so complete that subsequent action by means of $KClO_3$ was readily effected.) Heat to boiling and from time to time add small amounts of solid $KClO_3$ until all is dissolved. Cool, dilute to 500 cc., add a slight excess of potassium iodide crystals and titrate the iodine liberated with $Na_2S_2O_3$ in the usual way. Care should be taken not to add too much KI. If a precipitate forms add HCl until it dissolves.

The percentage of lead present is to be calculated as described in another article. The antimony is to be calculated as shown below. The tin is then to be found by difference from the mixed oxides of tin and antimony. The value of the sodium thiosulphate solution in terms of iodine having been found in connection with other work, its value in terms of antimony had to be found from the reaction equation:

$$SbCl_5 + 2KI = SbCl_3 + 2I + 2KCl$$

Whence 253.7 parts of I are equivalent to 120.2 parts of antimony.

Value in iodine of 1 cc. of the thiosulphate solution	=.xxxxx (*a*)
Value in antimony of 1 cc. of the thiosulphate $(a) \times \frac{120.2}{253.7}$	=.xxxxx (*b*)
Weight of the alloy used	= .xxxx (*c*)
Volume of $Na_2S_2O_3$ used	= .xxxx (*d*)
Antimony found = $(d) \times (b)$	= .xxxx (*e*)
Percentage of antimony = $100 \times (e) \div (c)$	= .xxxx

An attempt was made to use Yockey's method for the estimation of antimony, but after many trials it was abandoned as too difficult for practical purposes. His method secures the reduction of the antimony to the metallic condition after separating it from

the other constituents of the alloy. It comes down in an extremely fine state of division. Filter papers could hardly be made to retain it, and when they did, it spread over the edges of the paper by creeping. Even under the best care the method seemed to give too wide a range of results to be dependable. The following are some of the best results obtained from numerous efforts to apply Mr. Yockey's method:

Alloy taken.	*Antimony found.*	*Percentage.*
1.0062	0.1794	17.83
1.0276	0.0550	5.35
1.0600	0.1114	10.51
1.0312	0.1558	15.11
1.0146	0.0700	6.90

The amount of antimony really present ranged from 9 to 12 per cent as shown by the following figures, which show the results of the analysis of three samples by the method as described.

	Pb.	*Sn.*	*Sb.*	*Total.*
No. 4	85.10	4.95	9.83	99.88
	85.56	4.80	9.37	99.73
	85.75	4.57	9.73	100.05
Monarch Ball Metal	76.94	8.64	14.33	99.91
	76.53	8.52	14.95	100.00
Worn metal from the heating plant of Denison University	79.55	8.88	11.98	100.41
	79.99	8.36	12.05	100.40

Chemical Laboratories,
Denison University,
1908.

A STRATIGRAPHICAL STUDY OF MARY ANN TOWNSHIP, LICKING COUNTY, OHIO.[1]

FRANK CARNEY.

CONTENTS.

[1] This stratigraphical study of Mary Ann Township, as well as that of Perry Township which was published in Vol. xiii, pp. 117–130, plates I–VIII, 1906, of the *Bulletin of the Scientific Laboratories* of Denison University, and which is in-

INTRODUCTION

The exactness with which the formations of a given region may be mapped is conditioned upon several factors: (*a*) Thick mantle rock sometimes so covers the terranes that in the absence of youthful drainage one cannot get good sections. (*b*) Some areas bear heavy glacial drift and consequently present equal difficulties in measuring the formations; this condition may persist even beyond the territory formerly covered by ice, particularly where the drainage from the ice-sheet has made a great deposit of modified drift. (*c*) The attitude of the rocks also plays a part in the outlines produced by weathering: for example, a region that has suffered marked disturbance of an orographic nature will yield locally to agents of degradation, producing good sections for study; whereas in a region where the rocks are generally horizontal, and the erosion cycle was interrupted in early maturity, the conditions are not apt to be favorable to a precise mapping of the rocks. Since the products of rock-decay are shifted chiefly by stream work, it is apparent that the quantitative value of these several conditioning factors is largely a matter of physiography.

PHYSIOGRAPHY

Mary Ann Township, from the standpoint of physiography, involves some complexities. About one-half of the township was glaciated (fig. 1). The prevailing relation of drainage lines to the ice-front encouraged the development of outwash deposits. Some of these valleys are short but carried much water when the ice was contiguous; one valley was mature and for a short distance, may have sloped toward the approaching ice, in which case ponded-water occupied that portion of the valley.

In order to account for the two rock exposures which show good contacts of even part of the formations out-cropping in this township, and to understand why there are no more, it will be necessary

cluded as a part of this report, involving about fifty square miles in the eastern part of Licking County, Ohio, was undertaken at the suggestion of Prof. Charles S. Prosser, whose encouragement through conferences and aid in the field I wish now to acknowledge, as a requirement for a Minor while a graduate student in the Department of Geology at Ohio State University. It is a pleasure also to express my obligation to Mr. C. R. Stauffer, who spent two days with me in this area.

to review briefly what appears to have been the drainage history of the area. One of these cliffs is just north of Mary Ann Furnace, the other is on the western border of the township where Lost Run enters it. In several other places we find exposed ledges, especially on the slopes capped by the Pottsville formation. These two cliffs, it is supposed, mark critical points in the stream contest of the region.

a. An inspection of the topographic sheet (fig. 1) suggests that the oldest drainage line had a general southwest course through the area; this stream had its sources somewhere north or northeast of Mary Ann township. The villages of Hickman and Wilkins' Corners are situated in this valley, which was tributary to the "Newark river," a stream belonging to the reconstructed, southwest flowing drainage investigated by Tight.[2] The cross-section of this valley, for a distance reaching from a point a mile and a half east of Wilkins' Corners to the extreme southwest corner of the township, is a flat mature arc, as revealed by the rock contours. The present direction of stream flow shows that the drainage in this wide part of the valley has been directly reversed. The streams of the western half of the township now unite near Wilkins' Corners; this stream, Wilkins' Run, after flowing eastward for about one and one-half miles through the old, wide valley, follows a narrow rock-walled valley for about three-fourths of a mile, then joins the Rocky Fork. A short distance east of this place of junction we find the narrowest point in the valley of the Rocky Fork; from this point the valley flares both up and down stream; the upstream portion of the present Rocky Fork valley belonged to the "Newark river" system, and was captured by south-flowing drainage.

The ledges of rock along Lost Run also mark a divide which has been cut down by diversion, thus extending the drainage basin of another south-flowing stream.

b. When these drainage changes occurred, and the agent or processes involved, are directly important in the physiography of the area, and indirectly associated with its stratigraphy. Three time-definitions may be considered: (1) incidental to, or subsequent to, Wisconsin glaciation; (2) incidental to Illinoian glaciation, or at sometime during the Illinoian-Wisconsin interval; (3) antedating the Illinoian epoch.

[2] *Professional Paper, No. 13,* U. S. Geol. Surv., p. 18, 1903.

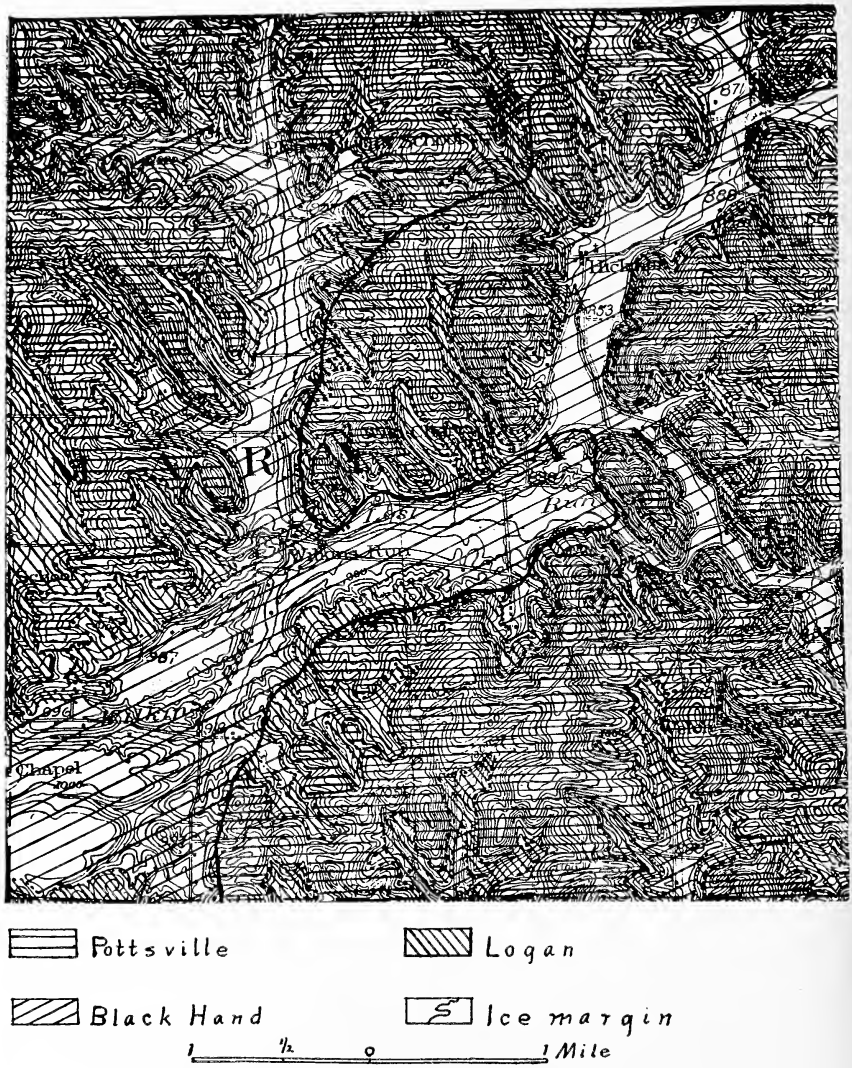

Fig. 1. The base map is a portion of the Newark Quadrangle, advance sheet, kindly supplied by Mr. J. H. Jennings, Geographer, U. S. Geological Survey.

(1) These diversions were not due to outlet-erosion of ponded water marginal to Wisconsin ice; this ice-sheet did not reach the area. If subsequent to this period, head-water capture was the mode of the diversion. Either differential tilting or warping, or the great inequality of volume and load favoring valley-deepening by the streams flowing away from the glaciated region, induced the piracy. In this case the lowered divide segment of the valley should be quite free from alluvium; it should bear no terraces of glacial outwash; it should be narrow and gorge-like.

(2) If the diversion dates from the interval between the two ice-invasions, and was brought about in any of the three methods just mentioned, the chief difference in the appearance of the lowered-divide segment of the valley would be one of age, that is, this segment would show a greater amount of weathering corresponding to the longer time period involved. Whether this segment would bear alluvium of ordinary stream-aggraded material, or of glacial outwash terraces, depends on the relation these valleys bore to the drainage from the Wisconsin ice. As previously stated, it does not seem likely that such drainage existed in the area.

(3) If the diversions were incidental to Illinoian glaciation, then the process of diversion must have involved a cutting down of the outlets of lakes held up in front of the ice. The depth of cutting in the lowered-divide segments of these valleys is so great that these hypothecated ice-front lakes must have existed for a long period. The basins involved in any one of them was so slight that the lakes must have come largely from the melting ice. Lakes lower their outlets slowly because outlet streams are almost entirely free of cutting tools; the great time involved in this outlet-erosion, would insure some evidence of wave-work about the lake shores as well as deposition-work of inflowing streams. The interval of time since the Illinoian glaciation would not remove completely all evidence of such shore-phenomena.

(4) As evidence of a pre-Illinoian date for these diversions we would require (*a*) greater age than described above in the cross-section of the lowered-divide segments of the valleys, (*b*) glacial alluvium present in these segments, (*c*) unmodified drift grading into outwash in, or contiguous to, the captured portions of the valleys, and (*d*) other instances of piracy in the neighboring unglaciated region representing the same movement in drainage adjust-

ment. Each of these four lines of evidence should be clear if the change in the drainage took place before the Illinoian glacial period.

This diversion may indicate an axis of uplift which presumably trended northeast and southwest, and was located westward of this area. Such a differential tilt would stimulate all streams flowing southeast or in a southerly direction, and retard streams flowing to the northwest or in a northerly direction. In consequence of this resulting differential in the cutting power of the streams, the rivers heading south or southeast of this township, encroached upon the drainage north and west. In this manner the divide in the vicinity of Mary Ann Furnace was gradually lowered, resulting in the leading to the southeast of all the drainage that formerly flowed past Wilkins' Corners to the southwest. These same factors, if operating, would account also for the narrow course in Lost Run valley on the western border of the township (fig. 9); with the cutting down of this divide the drainage basin of the southeast flowing streams was considerably enlarged by the accession of area northwest of the township.

While these two cases are the most obvious of the drainage changes in this area, there are also minor variations of slight consequence.

It is my opinion that these diversions took place before any ice came into the area, that is, that this differential tilt or warp and the resulting stream captures were pre-Illinoian.[3] One reason for this opinion is that the narrow parts of these valleys, that is, where the lowered-divides were located, now bear outwash deposits indicating that the divides were low enough, before the ice withdrew from the region, to become partly aggraded; another reason is that if the ice invasion preceded the captures, all the reversed segments of the southwest and west flowing drainage, as above indicated, must have been ponded, the water rising to the height of a col which it in time lowered. We would expect to find about the margins of these former lakes shore phenomena including either constructed beaches, wave-cut cliffs, or deltas. I am unable to find any such evidence of former water bodies. Furthermore the lowered-divide segments of these valleys are flat-bottomed because

[3] On the assumption that the oldest drift in this region is Illinoian in age; this drift may be Kansan.

aggraded with outwash, which has been terraced in places. In cross-section, these segments have a less aged appearance than their flood-plain portions indicate. The two coarse, somewhat resistant formations, the Sharon and the Black Hand, have retarded the usual effects of lateral planation work. The valley dependency of ice which extended eastward from Wilkins' Corners built a moraine ridge[4] across the old valley where it turns northward. This ridge blends into outwash which is terraced for miles southward.

Many other instances of capture, supposed to belong to the same aggressive movement of the south-flowing streams, have been studied, but not much has been published concerning them.

c. (1) Under normal conditions of stream capture the more speedy cutting down of the rock beds insures good exposures for stratigraphical study. The abnormal conditions in the area at hand is that whatever progress the streams thus made in degrading their beds was partially obliterated by the aggradational work of the ice-front drainage. The great distances over which the wash-material from the ice-front has been spread in eastern Licking county, especially in the valleys tributary to the Licking river, is a matter of common knowledge. These flood plains have been lowered some in post-glacial times. That the bed of the Rocky Fork from Mary Ann Furnace southward about a mile and a half is rock is due to rejuvenation. But the rock walls along the stream north of Mary Ann Furnace probably represent the vigorous work of the immediate ice-front drainage. Similar conditions marked a recessional stage of the Wisconsin ice, and developed the cliffs in the valley of Lost Run.

(2) As an agent of erosion, an ice-sheet in its distal portion is especially weak; there is very little evidence that the ice changed the outlines of even the bolder hills in this township. I do not attribute to the ice any over-deepening of valleys, or through-valley work here. Therefore the general effect of glaciation in this region, so far as a study of stratigraphy is concerned, has been to give the uplands a thin mantle of drift, and to bury the flood plains and side walls of the valleys beneath heavy outwash depos-

[4] F. Carney: "Valley Dependencies of the Scioto Illinoian Lobe in Licking County, Ohio," *Journal of Geology*, vol. xv, pp. 492–95, 1907, A picture of this ridge is shown in the *Bulletin*, vol. xiii, p. 138, 1907.

its and moraine terraces. Ice erosion has not lowered the major valleys so as to rejuvenate tributaries; in fact, glaciation in general has prematurely aged the streams of this area. Practically all the valleys bear flood-plain material, and during the post-Wisconsin interval a youthful stage of the erosion cycle has scarcely yet reached this far into the uplands.

STRATIGRAPHY

(*a. Formations*)

Cuyahoga Formation. Along the Rocky Fork, a little east of the eastern border of the township, the Cuyahoga appears, but the interval up stream before reaching the base of Black Hand is covered with alluvium.

Beneath the bridge across the stream at Wilkins' Corners, occur shales which may belong to the Cuyahoga. There is some indefiniteness, however, about this mapping owing to the fact that the upper part of the Cuyahoga may contain "arenaceous and argillaceous shales with some alternating layers of sandstone,"[5] thus resembling the lower part of the Black Hand formation which sometimes contains thin shaly layers.

Aside from these localities, I have not found anywhere in the township, outcrops of the Cuyahoga. That the formation has been deeply incised appears probable from the width of some of the aggraded valleys.

Black Hand Formation. Outcrops of this formation are widely distributed throughout the township. Actual contacts with the Cuyahoga, and with the superjacent Logan formation are rare. At the Lost Run section, the upper contact is well established; here the Black Hand measures 34 feet and 7 inches between Conglomerates I and II; below this I measured 29 feet and 4 inches above the covered flood-plain interval (fig. 2). Its lower part contains no very heavy beds, but towards the top of the section, nearing the horizon of the Allorisma shales or Fucoid layer (fig. 3), the strata thicken and have been used somewhat for building blocks. An unrecorded feature of the Black Hand formation is

[5] C. S. Prosser: "The Waverly Formations of Central Ohio," *The American Geologist*, vol. xxxiv, p. 359, 1904.

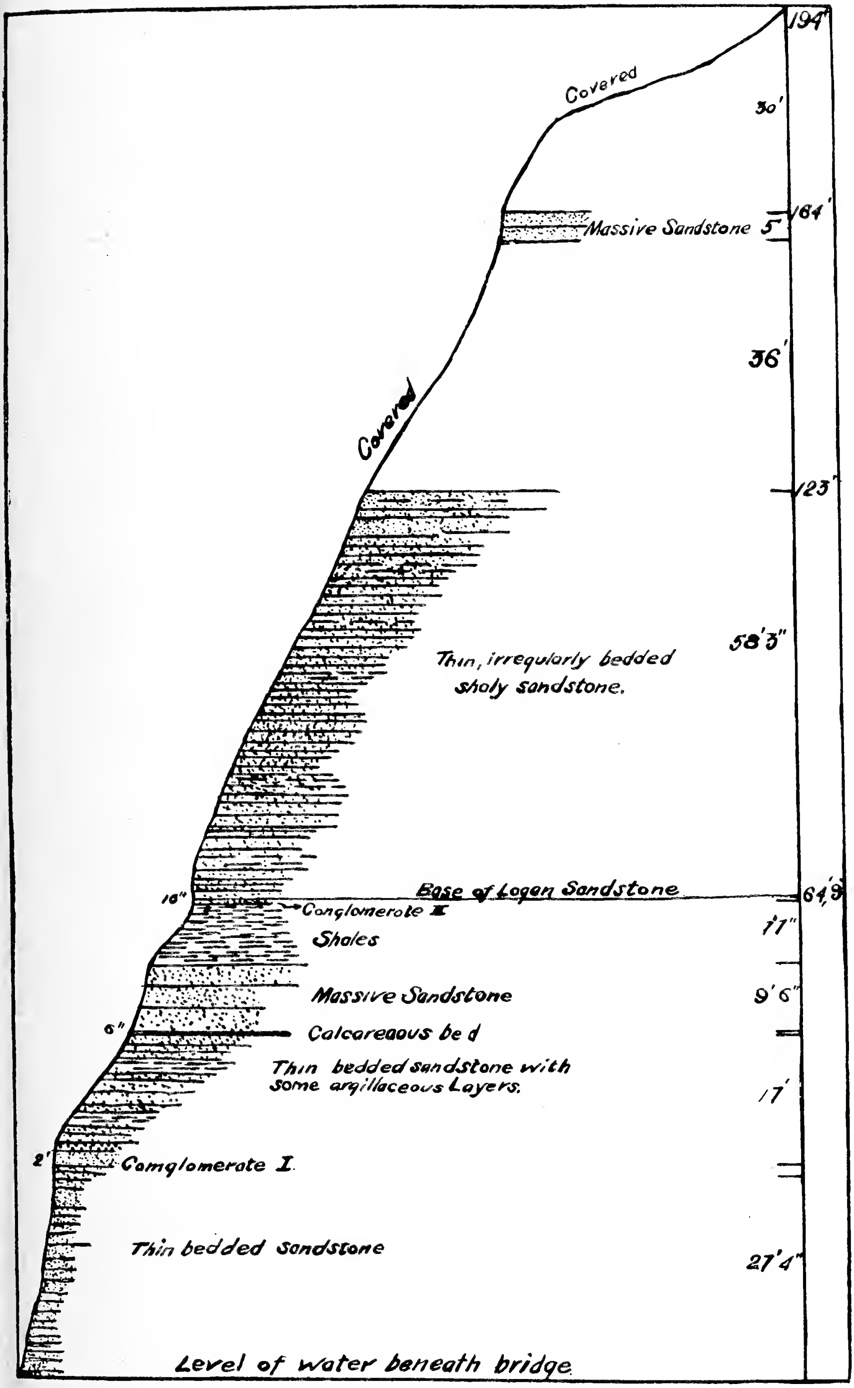

FIG. 2. The Lost Run Section.

the presence of a calcareous layer about 18 feet below Conglomerate II; such a bed, quite fossiliferous, exists in this section.

The most typical outcrop of the Black Hand in the township is the Mary Ann Furnace section (fig. 4). The contact with the Cuyahoga does not exist here, but by a line of levels[6] carried up the stream, it was established that about 31 feet of the formation is covered, slightly more than half being covered by alluvium, the rest by talus. At this section nearly 35 feet of Black Hand is

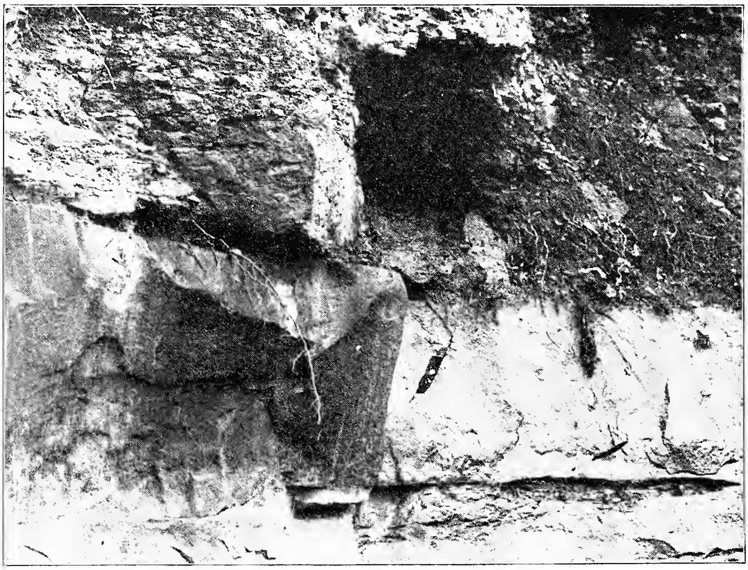

FIG. 3. Shows contact of the *Spirophyton* shales and the massive beds in the upper part of the Black Hand formation in the Lost Run section.

exposed, and, save for about 5 feet at the base of the Logan, the whole consists of quite massive beds. Conglomerate II here is a fairly coarse bed, 10 inches thick. The Allorisma layer was not noted in this section.

Along the principal valleys of the township the Black Hand formation frequently forms a shoulder near the foot of the valley

[6] The author wishes to acknowledge his obligation to C. W. Irwin, B.S. ('08) who wye-leveled the distance between the bridge at Hanover and the point where Wilkins Run joins the Rocky Fork.

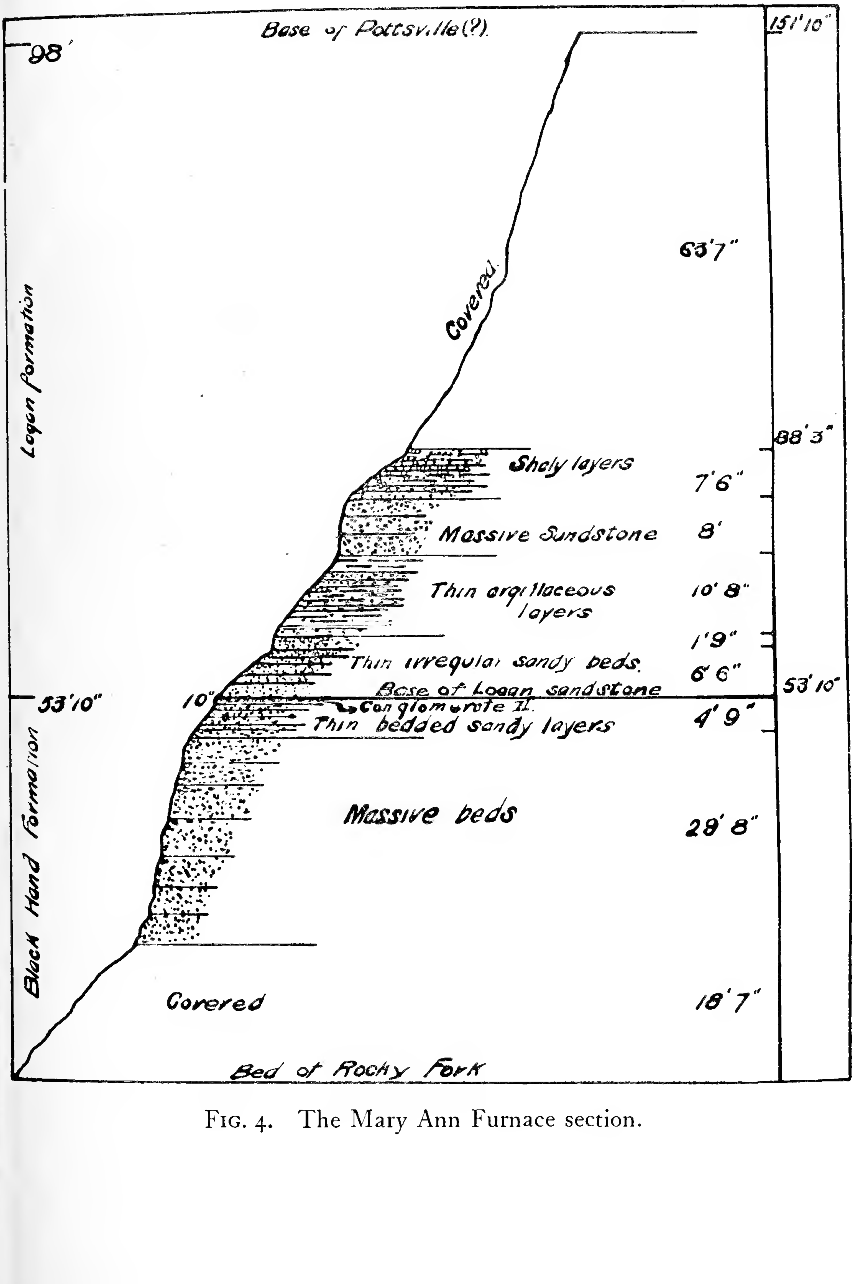

Fig. 4. The Mary Ann Furnace section.

walls; its presence is also indicated by a line of springs, a feature discussed more in detail in another part of this report.

The Black Hand, along both vertical and horizontal lines, is variable in texture, grading from thin fine sandy beds to heavier horizons, frequently quite coarse.

Logan formation. As one ascends from the valley floor along any of the roads leading to the uplands he generally notes first a sharp grade marking the horizon of the Black Hand formation, then gentler slopes which mark the horizon of the Logan sandstone (fig. 11). Wherever studied, I have found the Logan formation to consist chiefly of thin sandy beds, rather fine in texture, alternating with somewhat argillaceous layers. No stratum sufficiently thick or coarse in structure to make itself conspicuous through differential weathering was observed. Nevertheless, in the Mary Ann Furnace section there is one massive layer, a few feet above the bed which has been marked Conglomerate II. There may be an error in the location of the Conglomerate II, in which case the massive layer alluded to belongs to the Black Hand formation. In this section about 34 feet of the Logan is exposed. Above this I have measured approximately 63 feet before coming to the horizon where the Pottsville is on the surface; but this interval of 63 feet is unsatisfactory for a detailed study nor is its contact with the Pottsville sharp.

A study of the slopes associated with this formation throughout the township warrants the conclusion that the Logan, in vertical section, weathers more easily in its upper than in its lower beds. No exposure of the uppermost layers of the formation was found, but from the constant presence of Sharon conglomerate blocks, creeping down over the horizon of the Logan, I infer that the uppermost layers are the least resistant.

In the Lost Run section (fig. 2), about 47 feet of the Logan formation are sufficiently exposed to admit of measurement.

Pottsville Formation. The state geological map[7] gives but one area of the Pennsylvanian formations in this township, i. e., in the northwest corner comprising about one-third its surface. My study of the region shows that at least the Sharon member of the

[7] *Geological Survey of Ohio*, vol. vi, 1888. Edward Orton, Sr. So far as Licking county is concerned, this map follows the work of M. C. Read in his "Report on the Geology of Licking county," *Geological Survey of Ohio*, vol. iii, opposite p. 529, 1878.

Pottsville may be found practically on every hill rising from 150 to 170 feet above the flood-plain of the major drainage lines (fig. 1), while the upper part of the Pottsville shows conspicuously only in the southeast third of the township. At no point was I able to find the contact between the Pottsville and subjacent Logan. A probable reason for this condition has been given above. The thickness of the coarse phase of the Sharon member can be estab-

FIG. 5. The coarse phase of the Sharon, showing cherty fragments and quartzite pebbles.

lished with some degree of satisfaction by locating the fire-clay beds along the highway crossing the hill from Mary Ann Furnace to Wilkins' Corners; several aneroid readings make this measurement approximately 38 feet.

The Sharon wherever studied, is rather coarse, sometimes a conglomerate, locally showing vigorous stream work in the heterogeneous mingling of materials; in a few outcrops the fragments weigh one to four pounds, and are subangular, but mingled with

these slightly worn fragments are quartzitic pebbles (figs. 5, 6) that have long been subject to stream action. The coarsest phase of this conglomerate appears to occupy troughs in the Logan; this inference is based entirely on the vertical range of its outcrops, as no contacts showing the walls of Logan stream channels were found.

Fig. 6. A Sharon conglomerate block which has worked down the slope over the Logan; the bedding planes are now upright. This and Fig. 5 were taken southwest of Hickman.

(1) In two localities, one about one-half mile southwest of Hickman, and the other on the first sharp grade found in driving from Wilkins' Corners eastward over the hill to Mary Ann Furnace I noted in the Sharon angular fossiliferous cherty blocks. The fauna collected from these has been turned over to Mr. W. C. Morse, who is working on the Maxville. The fossiliferous content of the Sharon conglomerate was observed years ago by Read but I have been unable to learn that he succeeded in tracing the frag-

ments; he states[8] that the fossils were "identified by Mr. Meek as belonging to the carboniferous formation." If the fauna is found to be Maxville, then we can understand how the degradation of this horizon in early Pottsville time might account for its presence in the Sharon. A very careful search has been made both in this township and in Perry township directly east, but no Maxville limestone was found. This fossil content of the Sharon conglomerate affords an interesting problem.

(2) About two miles west of Mary Ann Furnace during the early seventies, a thin vein of coal was worked on the "Baker" place; the same horizon apparently was also worked on the road leading southwest across this high area. At this latter place the coal vein was buried by only a few feet. This coal horizon apparently had a very irregular horizontal distribution; in an outcrop between the two localities above mentioned, its presence is only suggested by a "blossom."

In one more place there is evidence of a former shallow coal working. This is at the top of the grade west of Mary Ann Furnace reached by taking the first road bearing to the north, and is near the corner made by this highway meeting one from the south. Just west of the corner reddish shale is found subjacent to fireclay; a few rods farther, we find more of this clay and a "blossom" above it.

On the supposition that the Logan formation in this area is not thicker than in the Mary Ann Furnace section, i. e., about 100 feet it follows that we have here 160 feet of Pottsville; in the absence of a definite contact between the Sharon and Logan, only this method remains for obtaining, even approximately, the thickness of the Pottsville.

b. Sedimentation

(1) The outlines of former land areas, and their altitude, may be indefinitely inferred from a study of the rocks. The constancy in the thickness of a given formation; a variation in its texture, horizontally and vertically; its structural peculiarities, whether genetic or imposed later, if any; its life, whether marine, littoral, or continental, whether prolific, sparse, or stunted; all tend to defining the continents of the past. Furthermore, the constancy or

[8] *Geological Survey of Ohio*, vol. iii, pp. 545–46, 1878.

inconstancy of these details as we pass vertically through a succession of formations shows whether the land area furnishing the sediments is gradually rising from the sea or is being transgressed by it, and indicates also the stage of the erosion-cycle as well as the general climatic conditions. But the organisms of the past periods, and equally too of the present, constitute the vitalizing fact of geologic studies, and at once furnish the basis for geography, either past or present.

Fig. 7. The slumping of mud sediments in the Bedford along Rocky Fork, Franklin Co., just west of Professor Prosser's "conspicuous tree" section (*Journal of Geology*, vol. x, 1902, pp. 277–278); the slumping occurred while the mud was fresh; sediments were then deposited over the distorted zone, and the river has recently brought it to view by undercutting the shales.

This consideration accounts for the following brief discussion of the sediments and associated conditions indicated by the formations studied in Mary Ann township; and since these formations belong to the Mississippian and Pennsylvanian periods, I have included in the discussion all of the former period as exhibited in central Ohio.

(2) *The Bedford Shale* formation save in its uppermost few feet is a fairly homogeneous mud deposit. It varies somewhat from place to place in color, the range being from chocolate red to a blackish gray. The texture of this formation suggests off-

shore deposits, and its thickness indicates a slowly transgressing sea, thus maintaining the depth of water that would assure freedom from the coarser terrigenous deposits (fig. 7). The nature of the sediment, furthermore, indicates a sea transgressing upon a land area that had long withstood erosion, a region already mantled with deposits of residual decay. Where, however, the Bedford shows some arenaceous layers inter-stratified (fig. 8), there is evidence of broad river deltas reaching out into the epi-continental zone. Here the irregularity of sedimentation occasioned by the seasonal or by longer cyclic periods of unusual water supply would

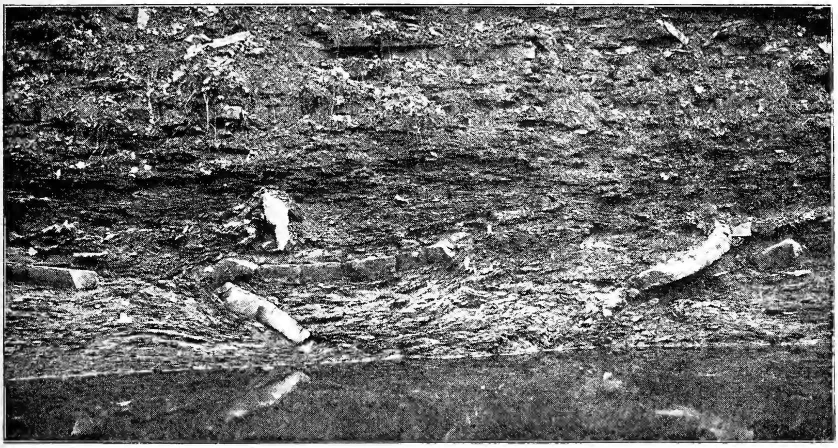

FIG. 8. Disturbed zone at the base of the Berea along Rocky river, Franklin county, described by Professor Prosser (*The American Geologist*, vol. xxxiv, 1904, p. 340, footnote).

extend the coarser sediments temporarily over areas where hitherto only the finer muds were being deposited.

Berea Formation. This series of thin bedded to slightly massive gritty layers above, below to arenaceous shales, about 37 feet in thickness,[9] illustrates rippling perhaps as no other horizon in the state displays the phenomenon. Along the Rocky Fork, up stream from the areas shown in figs. 7, 8, these sandy layers, for a vertical distance of 6 to 8 feet, consist of beautifully rippled beds averaging about two inches in thickness. Such a vertical range of conditions of sedimentation, usually interpreted as representing

[9] C. S. Prosser: *The American Geologist*, vol. xxxiv, p. 340, 1904, footnote.

shallow water, must imply a subsidence of the area receiving the sediments synchronous with the filling produced by the deposits. This conclusion is based on the assumption that such a uniform condition of ripple marks persisting through a considerable vertical range implies a constancy of sedimentation factors. Towards the upper part of the Berea, however, the beds thicken, becoming more sandy, thus suggestive of littoral sedimentation.

Sunbury Formation. This horizon of rocks consists chiefly of shales locally arenaceous, but in the main, black in color and bearing a considerable fauna. Both the fauna and the lithological aspect of the formation indicate marine sedimentation. On this principle, then, the water area in which the next older formation, the Berea, was laid down, continued to transgress the land, thus maintaining a horizon of marine deposition.

Cuyahoga Formation. This formation consists of shales and sandstones, the upper boundary of which was for some time given as Conglomerate I.[10] Later studies,[11] however, have shown that this conglomerate horizon is not persistent, and furthermore, that even where found it overlies beds that do not have the Cuyahoga characteristics. So far, however, as the process of sedimentation involved in the Cuyahoga beds admit of interpretation, it is evident that the quick transition frequently noted from fine to coarse textured layers probably indicates a somewhat static relationship of land and water which would result in the coarser sediments locally reaching out over mud deposits. This supposition accounts for the transition from shale to an arenaceous or even a conglomerate horizon. When, however, mud deposits follow, in the vertical succession, the sandstone or argillaceous shale, which is the prevailing relationship in the Cuyahoga inasmuch as it contains more shale than any other textured rock, it is surmised that the predominating tendency of the water body was transgressive. I feel nevertheless that a closer mapping of the Cuyahoga and the conglomerate horizon by which the top of the formation was formerly fixed will reveal much horizontal variation, and that the meaning of this inconstancy is a closely balanced relationship during the early and late Cuyahoga times between the rate of deposition and the rate of transgression by the sea.

[10] C. L. Herrick: *Bull. Denison University*, vol. iii, p. 26, 1888.
[11] C. S. Prosser: *The American Geologist*, vol. xxxiv, p. 359, 1904.

Black Hand Formation. This horizon of rocks overlying the Cuyahoga is generally called a conglomerate. The conglomerate phase is indeed remarkably developed in many localities; on the other hand the formation consists locally of fine sand and even of argillaceous sands. From the standpoint of methods of sedimentation the striking feature of the Black Hand is its thickness (fig. 13). We note, not infrequently, ledges often about 100 feet thick where it shows very little irregularity in texture. This constancy of shallow water or of littoral sediments implies a sustained relationship of land and water brought about through the rate of deposition balancing the rate of land subsidence or of transgression by the sea. Where, however, we find this formation interrupted vertically by beds somewhat coarse and often conglomeratic there is evidence of more vigorous erosion, or of tidal assortment combined with current scour, resulting in the localization of coarser deposits. Accordingly the conglomerate beds of the Black Hand are not consistent in horizontal development. For this reason we are inclined to favor the wave and current rather than the stream-erosion explanation for these coarser beds.

The Logan Formation. This formation consists of sandstone, somewhat clayey in character, with now and then a thin layer of shaly sediments. The prevailing condition of sedimentation during this period is certainly not clear. The irregularity of the formation in horizontal extension, however, gives some suggestion. Furthermore, the general thickness of its beds leads to the same conclusion, namely, a transgressing sea following up rivers already mature in their drainage-cycle-position, with the rate of deposition lagging considerably behind the rate of transgression. The general absence of mud deposits and the fine texture of the sandstone in this formation both indicate a nearby source of sediments, presumably the working over of those last developed and of continental sediments. Further evidence leading to this same conclusion is found in Conglomerate II, a persistent coarse horizon marking the boundary line between the Black Hand and the Logan. This conglomerate is widespread but not thick, its maximum depth usually being less than two feet. This relationship is suggestive of transgressive deposits marking a slow growth of a sea over the land in the gradually deepening of which water-body the Logan sandstones were laid down.

The Pottsville Formation. The Sharon member of this forma-

tion is prevailingly coarse; locally it is exceedingly coarse. A variation along horizontal lines is the most striking feature of the Sharon. The transition laterally from fine, even-textured sandstone, to irregularly bedded conglomerate masses ranging from quartzite pebbles to units 4 or 5 inches or even larger of siliceous fragments, was long ago noted by geologists in Ohio. The evidence of regressive continental sedimentation in the Sharon is quite conclusive.[12] Terrestrial streams here have followed a retreating shore line, their flood plain and alluvial fan deposits being indicated now by the coarser phases just alluded to. Such a transportation of river deposits would be witnessed in a tilt or warp of an ocean-border tract, the movement progressing inland. Thus in the littoral zone finer sediments would accumulate, irregular in horizontal distribution because of vigorous streams, a condition less favorable to fauna; these sediments, the Logan, would suffer erosion locally, and in the channels thus made later sediments, the Pottsville, were deposited.

The patches of fire-clay and of coals found in the upper Sharon and later Pottsville indicate a balanced condition between erosion and deposition which insured a wide littoral zone and the development inland of extensive flood-plains.

c. Geographic Influences Arising from this Stratigraphy.[13]

In the arid southwest parts of the United States, the crude water signs of the Indians have often pointed the white man to a spring. The government topographic maps covering sections of this region of sparse rainfall give the location of many springs. Throughout the longer-known and more-traveled desert areas of the world, the few oases have fixed the routes taken by caravans. Numerous books are available detailing facts that bear on the geographic influence of springs in arid climates. But into whatever land man has gone, humid as well as arid, springs have had a part in his activities. So far as America is concerned, I am not aware that a quantitative

[12] D. White: *Bull. Geolog. Soc. Am.*, vol. xv, p. 279, 1904, urges that a transgressing sea was associated with the deposition of the Pottsville sediments.

[13] The remainder of this paper is reprinted from *The Popular Science Monthly*, vol. lxxii, pp. 503–11, 1908, where it appeared under the title, "Springs as a Geographic Influence in Humid Climates."

study of the influence of springs in humid regions has been undertaken.

(1) While mapping the stratigraphy of an area of approximately 25 square miles in central Ohio, where the annual precipitation is about 40 inches, the influence exercised by springs was given particular attention. In this area the upper formations of the Mississippian, and the lower of the Pennsylvanian periods come to the surface. The vertical series of rocks involves two

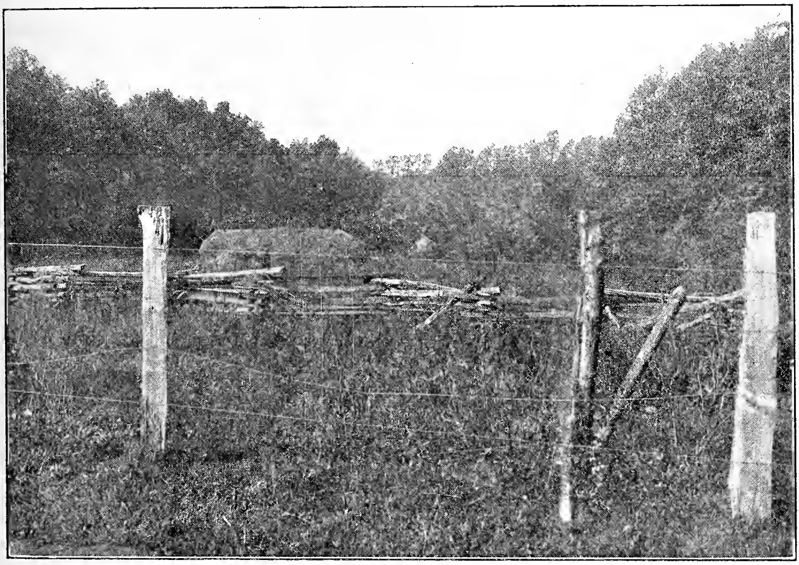

Fig. 9. Looking up-stream through the narrow, former col, part of Lost Run. The section shown in Fig. 2 was measured beneath the trees standing on top of the cliff in the middle distance. A primitive log house marks the location of a constant spring.

horizons of coarse clastic sediments, the Black Hand of the earlier period, and the Sharon member of the Pottsville, which is the lowest formation of the later period. The Black Hand overlies the Cuyahoga, which in central Ohio "is composed largely of bluish and grayish shales and buff sandstones."[14] Subjacent to the Sharon is the Logan formation consisting chiefly of "buff arenaceous shales to thin bedded sandstones."[15] The Black Hand is a mas-

[14] Charles S. Prosser: *Journal of Geology*, vol. ix, p. 220, 1901.
[15] *Ibid.*, p. 231.

sive sandstone, locally conglomeratic; the Sharon is less massive, and locally coarser; this characterization of these two formations applies specifically to the area studied. While neither of these sandstone formations overlies impervious beds, yet in themselves they are variable in texture and structure, and the region is so maturely dissected (fig. 15), that conditions are very favorable to the development of springs. Furthermore, the Logan also contains beds that are water bearing.

(2) The early settler in agricultural lands found a spring, if possible, and then built his log house. Others coming into the

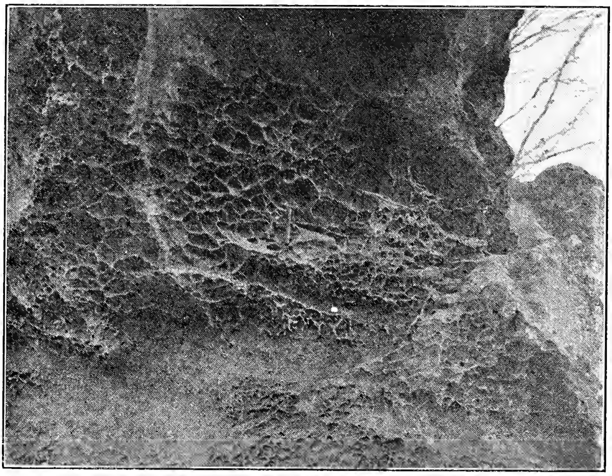

FIG. 10. The iron content of this Sharon rock induces the "honeycomb" effects in weathering, and also makes the springs less desirable.

region made similar locations. Settlement generally moved along streams, since in the absence of roads valleys are more accessible. If the valley has been developed in water-bearing formations, which are not much tilted, springs border the bottom land on either side. Both topographic convenience and the presence of water tended to confine the earliest habitations to the valleys. Later settlers spread over the intervalley areas, building their houses in proximity to springs.

Primarily the highways lead from house to house; eventually, however, several factors become operative before the roads are permanently fixed. In the case of a valley having a commodious

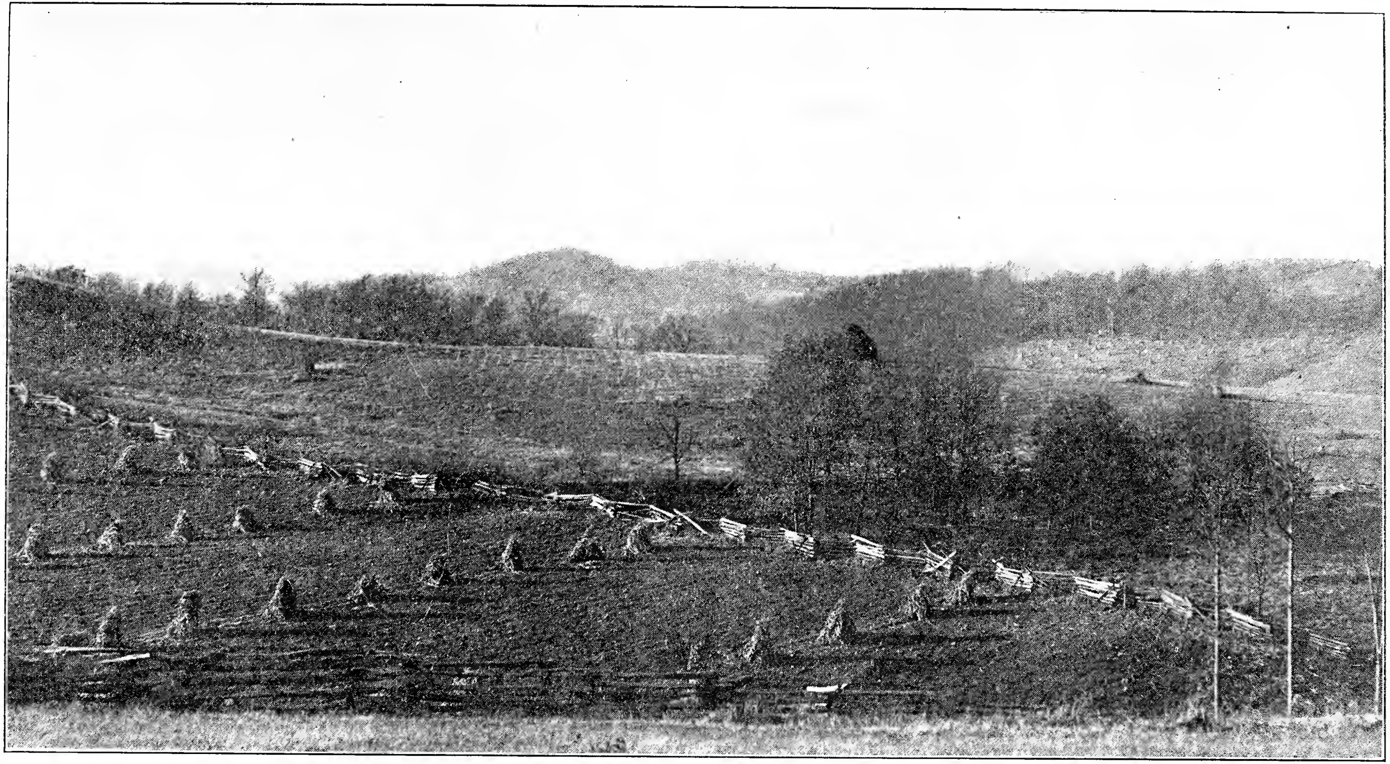

FIG. 11. The gentle slopes of the Logan formation afford good farms, but few springs for dwellings. Twice as many houses are found along the lower contours of the Black Hand formation where water is plentiful.

flood-plain, but not extensive enough to warrant the maintenance of roads on each side, the slope bearing the better springs was normally the decisive factor; the homes on the opposite side would be approached by fords and lanes, or by only the latter if located near a transverse highway. In the uplands the permanent lines of traffic appear to take courses that will accommodate the greatest number without making too great sacrifice in distance; even then some dwellings are isolated. The isolation may continue but one

FIG. 12. The tiny rill of a spring that has already developed a small basin in the Black Hand formation.

generation, or until the desire to live on the highway overcomes the convenience of water and the associations of the hearth; the latter factors have prevailed wherever we see an isolated frame house, whereas a deserted log cabin means the dominancy of the former.

Moreover, the intervalley highways sometimes exhibit an economic influence. When the area is heavily timbered, and lumbering rather than agriculture is the initial occupation, the roads made

in connection with logging and milling may become permanent. For example: North of Wilkins' Corners (fig. 1) the second highway leading west ascends about 160 feet in one-half mile; this road parallels a valley a few rods to the left, where the same horizontal distance involves only half the grade; the original highway did follow the valley, connecting the two houses. But loghaulers from the wooded upland located their main road where it would command as much of the area as possible, approaching it

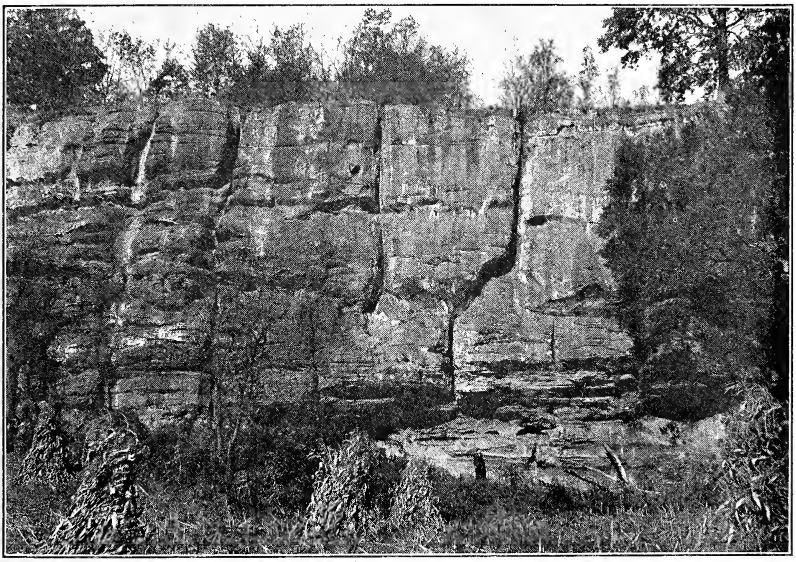

FIG. 13. The Black Hand formation is generally a coarse, irregularly bedded sandstone, yielding a copious supply of spring water.

by spurs along contours. This traffic fixed the road where it is, though it has never led directly to a dwelling; property complications diverted the second house up the valley to it, the original roadway being abandoned. A similar influence in highway location due to mining operations is seen one and one-half miles west of Mary Ann Furnace in the road trending southwest from the one leading to Wilkins' Corners. Some 50 years ago a vein of coal on this slope was worked for local use, and was approached from the west, thus opening a highway that has served little use since.

It is evident also that so far as the intervalley roads are concerned, the topographic factor made slight appeal to the locating

engineers, an ox-team and its driver. If the most direct line between houses, i.e., between springs, crossed a sharp hill, the highway went directly over rather than follow a contour, or take even a gentler, if slightly longer, grade. I have noted several places where in the past decade these sharp grades have been

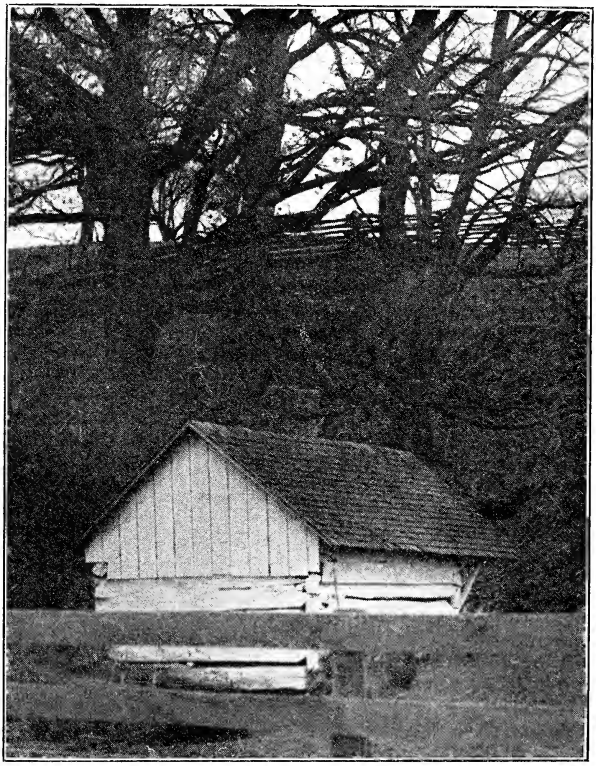

FIG. 14. Sawed shingles and a few boards are used in lengthening the years of service of this rough-hewn log spring house.

removed by a detour, but two generations had dragged themselves wearily over the hill.

(3) The convenience of good water, or of rich bottom lands in the valleys, factors that would seem to have much weight with the early settler in choosing a location, is of secondary importance when opposed to an inherited topographic proclivity. A man reared among hills, however barren, has a latent tendency to plant

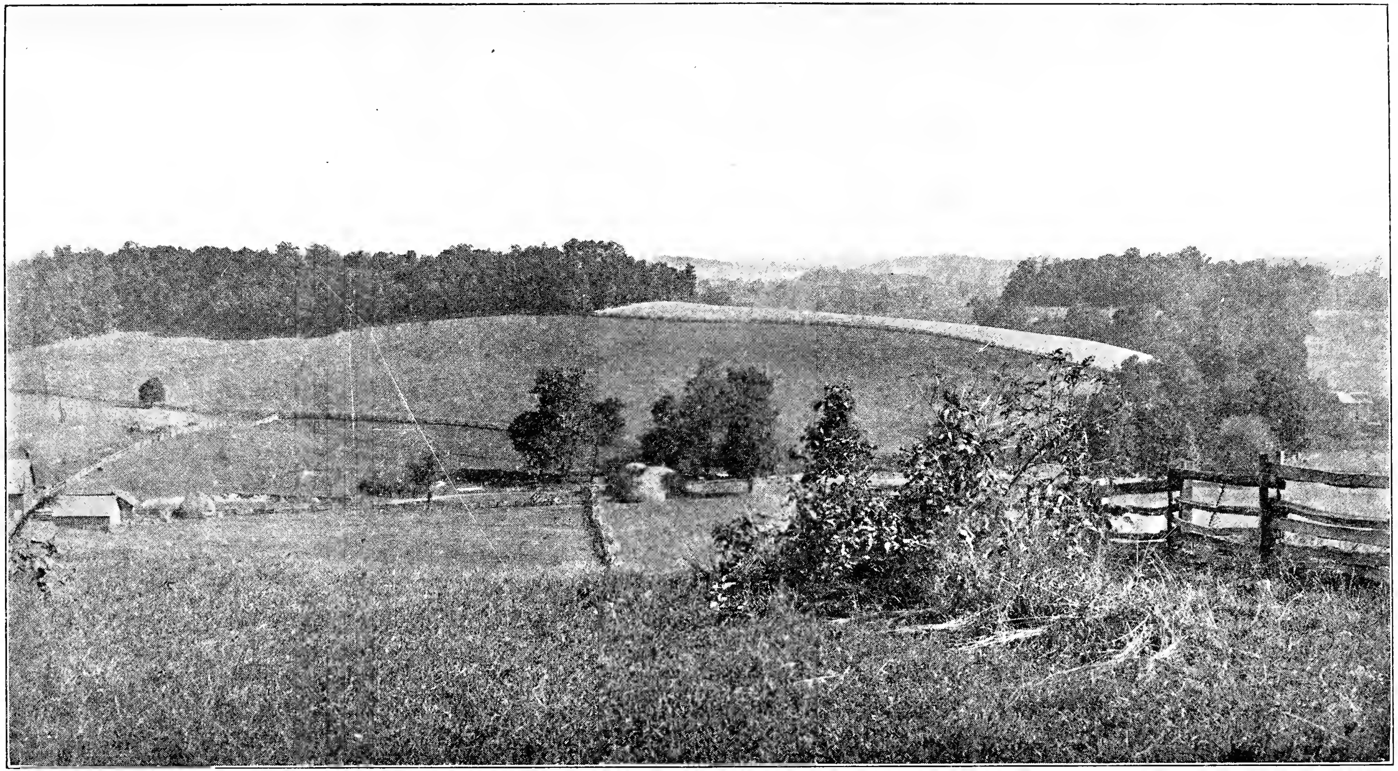

Fig. 15. A mature stage of erosion is a condition favorable to numerous springs.

his new home in similar topography. This bias, developed through environment, whether inherited or acquired by the individual, is illustrated in the choice of lands made by Welsh immigrants who came into Licking county, Ohio, early last century; they passed by thousands of acres of lowlands, the richest in the state, and selected farms in a rugged portion of the county, still owned by their descendants, and even now designated "The Welsh Hills."

(4) But in the region to which special study was given, the geographic influence of springs is obvious. There are 203 houses in the township, 148 of which are built at springs; some of the 55 using wells formerly depended on springs. Both the horizontal and vertical distribution of these dwellings is largely a matter of stratigraphy of which the springs are a manifestation. It should be noted, however, that the localization of houses near Mary Ann Furnace is due to the fact that over sixty years ago iron ore, found in the neighboring hills, was reduced here; stoves also were manufactured at this place. The furnace was destroyed in 1853, but the houses are still in use.

(a) Over 50 per cent of the dwellings with springs are in the horizon of the Black Hand formation (fig. 13), which borders the flood-plains of all the valleys, a distribution made possible because the formation has an eastern dip of about 25 feet per mile. The springs in the Black Hand are numerous and copious (fig. 12), partly because of the thickness and texture of the formation, also because of its subjacency to horizons that carry water freely.

(b) In the Logan formation, I have mapped 30 houses with springs. There is doubt concerning a few of these, an indefiniteness occasioned by the absence of contacts. The Logan sediments suffered erosion contemporaneously with Pottsville sedimentation; furthermore, the Logan, in comparison with its contact formations, the Black Hand and the Sharon, weathers easily, producing gentle slopes. These two conditions make it doubtful about the exact horizon of a spring near either the top or the base of the Logan.

(c) Slightly less than 17 per cent of the houses with springs are found in the Sharon. The areal extent of all the exposed formations diminishes vertically, hence the number and the volume of the springs decrease; the value of the land for farming also decreases with altitude. A further fact concerning the springs of the Sharon is their content of iron, making them less desirable than springs in either of the lower formations (fig. 10).

The township contains no extensive areas of outcropping coal measure or Pennsylvanian formations, save in the south central portion; elsewhere disintegration has left only outliers. In the area west of Mary Ann Furnace, covering several square miles, and another along the eastern border of the township, there are eighteen houses, three of which, now occupied, have springs. For the entire township, the average number of houses per square mile is about eight; for the horizon of the coal measures, it is less than two. That springs are rare is not the sole cause for the discrepancy; the bleakness of the upland, and the unproductiveness of the soil are contributory factors.

About 10 per cent of the homes with springs are built on glacial deposits. The drift is localized chiefly in the valleys. The ice-sheet covered approximately two-fifths of the township, but left scarcely a veneer of drift on the intervalley areas. While fourteen springs have been mapped as belonging to the drift, it is quite probable that a good fraction of these are fed by water courses from the Black Hand formation. Of the wells noted, 56 per cent are in glacial deposits.

Still another evidence of the influence due to springs is seen in the fact that of the eight deserted houses in the townships one is in the Black Hand formation, one in the Logan and six in the Coal-Measures, the horizon practically without springs. It is noted also that 22 per cent of the dwellings are off highways, an isolation due entirely to springs. Furthermore, dairying has always been carried on in this region (fig. 14) because in the summer season the springs furnish cool water for handling milk.

SIGNIFICANCE OF DRAINAGE CHANGES NEAR GRANVILLE, OHIO[1]

E. R. Scheffel

OUTLINE

Introduction

Physiography of Area and Nature of Problem

This paper will endeavor to prove by the intensive investigation of a limited area a dynamic phenomenon which has probably influenced much of the drainage history of Ohio. The area considered includes practically the whole of Licking county, with the village of Granville as the approximate center and offering in its physiographic environment the most decisive proofs for the contentions made.

"Licking county lies near the center of Ohio and its present drainage is by the Licking river, which is formed at Newark by

[1] Work done under the direction of Prof. Frank Carney, Denison University, as partial requirement for the Master's Degree.

the confluence of three streams, the North and South Forks and Raccoon creek. These streams form a hydrographical basin which is very nearly coextensive with the county lines."[2] To the west of the headwater portions of the North and South forks, narrowings followed by decided flarings are noted. By correlating these narrowings and following the most unbroken line of high rock altitudes the conclusion is reached that a former divide passed through Granville[3] in an approximately north-south direction.

DRAINAGE CHANGES

Before considering the cause of the diversions in this area it may be advisable to give a general discussion of the subject, drainage changes.

The causes for such changes may be somewhat arbitrarily divided into three heads,[4] though it is quite possible for two or all to be inextricably associated. These causes are piracy, glaciation, and diastrophism. Others, less important and more localized, will be omitted.[5]

1. *Piracy.*[6] This term is applied when one stream "steals"[7] another. Primarily piracy is resultant from the more rapid headwater growth and deeper cutting of the pirate stream as compared with the robbed or beheaded drainage line. Davis gives a dramatic account of the contest for supremacy between the east and west flowing streams draining the Blue Ridge.[8] The entire Appalachian system is also cited as witnessing many such contests.

Though these contests may not represent in every instance typical cases of piracy, still, in a broad sense, when by the greater relative growth of one stream its divide migrates, thus lessening the drainage area of another, the first has in reality robbed the second.

[2] W. G. Tight: *Bull. Sci. Lab. Denison Univ.*, vol. viii, part ii, p. 36, 1894.

[3] F. Leverett: *Glacial Formations of the Erie and Ohio Basins*, Monograph xli, U. S. Geological Survey, p. 160, 1902.

[4] *Ibid.*, pp. 196–200.

[5] G. D. Hubbard: *The Ohio Naturalist*, vol. viii, p. 349, 1908. A. C. Lane: *Bulletin of the Geological Society of America*, vol. x, p. 12, 1899.

[6] I. Bowman: *Journal of Geology*, vol. xii pp. 326–334, 1904.

[7] R. D. Salisbury: *Physiography*, p. 176, 1907.

[8] W. M. Davis: *Bulletin of the Geographical Society of Philadelphia*, vol. iii, pp. 213–244, 1903.

For simplicity the causes inducing piracy will be considered with glacial and diastrophic forces as quiescent. Three may be named: Topography, stratigraphy, rainfall. Each of these will be considered alone, disregarding the other factors.

Topography. Of two drainage systems separated by a divide, the one lying on the steeper slope has a decided advantange. The impetus given its waters permits it to cut more deeply and rapidly than its opponent. The divide consequently migrates; the feeding areas of the weaker stream are gradually gained and more or less of its headwater drainage captured by the stronger. The most striking cases of piracy occur when the two contending major lines flow approximately parallel. This may conceivably permit the sudden capture of almost the whole of the weaker system. When the major streams flow in opposite directions from the divide separating them,[9] as in the Blue Ridge, the ground is sharply contested and the diversion of drainage less evident.

Piracy may occur between systems of drainage or within a system. The same laws are operative in either case.

Stratigraphy. Differences of structure and dip in the strata over which they flow may give one of two streams a decided advantage over the other. Thinly bedded strata offer less resistance to weathering, corrasion and corrosion than do heavily bedded strata. The direction of outcrop relative to stream flow is also a factor in erosion. Chemical composition and structure, whether unmetamorphosed sedimentary rock or igneus or metamorphic rock, must also be considered.

By advantageous combinations of the above one stream may cut its channel more rapidly and eat headward faster than its neighbor, thus securing substantially the same conditions as in the case of the stream with steeper slope.

Rainfall. It is evident that, all other conditions being equal, of two opposing streams the one in the area of heaviest rainfall would have the greatest advantage. There are many instances where a divide obstructs the prevailing winds causing the precipitation of nearly all their excess moisture on the windward side. In such areas it is evident that the streams draining the territories of greatest rainfall would ultimately gain an advantage similar to that favored by topography or stratification.

[9] F. S. Mills: *Journal of Geology*, vol. xi, pp. 670–678, 1903.

2. *Glaciation.*[10] This has been considered the principle factor in changing the drainage over considerable areas. Tight[11] ascribes the reversals in the drainage of Ohio to this cause. Leverett inclines to the same explanation for this and other areas. Leverett has shown a tendency, however, to admit the possibility of another explanation for changes in glaciated areas.[12] Carney,[13] particularly, has suggested a theory of preglacial diversion for certain Ohio streams.

Glaciation may effect drainage in various ways, i. e., by planing topography and by eroding divides.

Planing Topography. This may be accomplished by the erosive action of a glacier combined with its later passivity with resultant heavy aggradation. This may effect a changed drainage having the same general course as the preglacial, or the débris filling may take a slope at variance to the original valley bottoms necessitating a very different and perhaps reverse course.

Eroding Divides.[14] Cols may be cut directly by the corrasive action of glaciers. Again, a valley may be dammed by a morainal deposit[15] necessitating outflow of the drainage in a new direction, sometimes over rock divides. Perhaps the most commonly recognized cause is damming[16] of the headwater areas by the ice-front. In such instances the water is ponded between the ice and divide, and is forced to seek an outlet over the lowest point in the latter. Eventually a deep channel or channels may be cut through it. The deposition of drift in such a lake would normally be heaviest near the ice, with the possible result of a change in the slope of the bottom, downward toward the col, leaving on the retreat of the ice a reversed drainage. Sometimes glacially formed lakes

[10] R. S. Tarr: *Physical Geography of New York*, pp. 154–184, 1902. G. D. Hubbard: *Ohio Naturalist*, vol. viii, pp. 349–355, 1908. W. G. Tight, J. A. Bownocker, J. H. Todd, and Gerard Fowke: *Special Paper No.* 3, "The Preglacial Drainage of O.," O. State Acad. of Sc.

[11] W. G. Tight: *Bull Sci. Lab., Denison Univ.*, vol. viii, part ii, pp. 35–61, 1894.

[12] *Bull. Sc. Lab., Denison Univ.*, vol. ix, part ii, p. 21, 1897. *Monograph* xli, p. 199. G. C. Matson: *Jour. of Geol.*, vol. xii, p. 139, 1904.

[13] *Bull Sc. Lab., Denison Univ.*, vol. xiii, p. 151, 1907.

[14] F. Carney: *American Journal of Science*, vol. xxv, pp. 217–223, 1908. T. L. Watson: *Univ. of State of N. Y., State Museum Report* (No. 51), vol. i, p. 171–2, 1899. H. L. Fairchild: *Bull. Geol. Soc. Am.*, vol. x, pp. 27–68, 1899.

[15] *Ibid.*, vol. vi, pp. 354–5, 1895.

[16] G. K. Gilbert: *Bull. Geol. Soc. Am.*, vol. iii, p. 286, 1897.

survive the withdrawal of the ice, at times being confined in valleys between two moraines.[17]

While the theory of the erosion of divides is quite plausible it seems not improbable that this may have been pushed too far. The overflowing water would be deprived of nearly all its cutting tools and would consequently be dependent almost entirely on corrosion for dissolving down its spillway. The time necessary for such a process would seem greater in certain instances[18] than could be granted for the favorable position of the ice-front.

Changes of drainage by glaciation may be ephemeral, lasting only through the period when immediately affected by the ice, or such changes may be of great permanency, outlasting indefinitely the period of glaciation. All degrees of endurance may be found between the two extremes.

3. *Diastrophism.* This term includes all crustal movements. Diastrophism is the most potent and far-reaching of all the causes inducing drainage changes. In many examples explained by piracy or glaciation it is probably an unseen factor. Slight movements are difficult to determine, particularly when inland, and for this reason have not been accorded their full share of influence.

M. S. Campbell has formulated the theoretical effects of land movements occurring under ideal conditions.[19] He also describes specific instances of drainage changes and applies these theories to them.[20] His "Law of the Migration of Divides" is a brief summary of the theoretical side of the question. It is as follows:

"When local radial movements occur in any region the stream divides in that area will tend to migrate;[21] the direction in which they move will be determined by the character of the crustal movement; and the extent of the migration will depend upon the amount of movement and the local obstacles which the streams may encounter. If the movement is upward the divide will tend to migrate toward the axis of uplift; and if the movement continues

[17] R. D. Salisbury: *Loc. cit.*, p. 280.

[18] F. W. Harmer: *Quarterly Journal of the Geological Society* (London), vol. lxiii, pp. 470–514, 1907.

[19] *Journal of Geology*, vol. iv, pp. 567–581, 1896.

[20] *Ibid.*, pp. 657–678. See also L. G. Westgate, *American Geologist*, vol. xi, pp. 245–260, 1893.

[21] A phase of the migration of divides consequent on faulting by W. S. T. Smith, *Journal of Geology*, vol. v, pp. 809–812, 1897.

long enough, and other conditions are favorable, it will reach the axial line and there remain. If the axis coincides with a divide already established, it will hold the latter stationary unless some stronger influence causes it to migrate.

"If the movement is one of subsidence the divide will tend to migrate away from its axis; and will continue in that direction until the streams attain a condition of equilibrium. The migration of the divide away from the axis of depression generally results in the formation of a stream along the axial line; and the direction in which it flows will depend, in a great measure, upon the pitch of the axis of the fold."

A peculiar phase of stream diversion, evidently not in the literature but theoretically possible, may be considered. A slight differential movement resulting in a steepened slope on one side of a divide and a lessened slope on the other, would encourage head-water cutting on the first mentioned side and aggradation on the second. In time the divide would be cut through, the stronger stream gradually diverting the weaker by cutting back into its aggraded bed. Other theories have always implied a backward cutting through solid rock under such conditions, but the very movement which induces this cutting on the one side encourages aggradation or at least the accumulation in situ of the products of erosion on the other, thus giving the proposed theory a strong basis for support.

Of the local movements in the United States those in the Great Lakes and New England areas have been given considerable attention.[22]

Tilting is probably never the only factor entering into drainage changes; rock structure and dip, glaciation, the revolution of the earth, etc., may have greater or lesser shares in the responsibility.

DETAILED DISCUSSION OF LICKING COUNTY STREAMS

Raccoon Creek. This stream will be taken as a type and a minute discussion of it given to prove the change of drainage and

[22] J. B. Woodworth: Bulletin 84, *New York State Museum*, p. 66, 1905. A. W. Grabau: *Ibid.*, (no. 45), vol. ix, pp. 55–66, 1901. G. K. Gilbert: U. S. Geol. Surv., *Annual Report* no. 18, pp. 601–47, 1898. G. K. Gilbert: *Smithsonian Report*, pp. 237–244, 1890. Also "Preglacial Valleys of the Mississippi," by F. Leverett, *Journal of Geology*, vol. iii, p. 763, 1895.

its cause. Raccoon creek rises in the west by northwest part of Licking county, flows southeast to Alexandria and then almost due east to its junction with the South Fork of the Licking at Newark. The old topography of the headwater area has been so completely masked and smoothed by a filling of glacial débris that interpretation of the preglacial history is difficult. This interpretation must depend largely on the evidence of the less obscured area downstream. Beginning near Alexandria the drift filling slopes sharply eastward and the great width of the valley is revealed for several miles, until near Granville where it suddenly narrows, passing between rock walls. The appearance of this valley suggests a large amphitheater opening eastward: to the west, a sloping drift surface; southeast and east, except at the gap noted, rock walls of the Waverly Series. The northern wall consists for apparently several miles of a drift divide separating this valley from a similar one constituting the headwater area of Brushy Fork. The length of this drift divide, considered in connection with the narrow rock-walled outlet to the east, is strong evidence that a former stream headed north of the present divide and following the large valley already mentioned passed westward through Alexandria. For convenience this old drainage line may be called the Alexandria river. (Fig. 1.)

The narrowing in the Raccoon continues for about a quarter of a mile east where the junction with an "Old" north-south tributary valley[23] permits a decided southward flaring. The east wall of this tributary valley reaches out as a spur into the valley of the Raccoon, producing its minimum width. The constriction is further emphasized by the presence of a glacially worn rock hill known as Sugar Loaf, lying in the valley slightly northwest of the spur. East of Sugar Loaf about a third of a mile is a similar but larger rock hill, "Mount Parnassus." This physiography suggests that a divide shaped like a reversed *S* once existed at this point; the two isolated rock hills being the remaining fragments of the outermost curves of the *S*. These two points, it may be noted, correspond very nearly with the east-west limits of the village of Granville. (Fig. 2.)

From this divide area eastward about three miles the valley again widens, the greater width being principally due to the numer-

[23] E. R. Sheffel: *Bull. Sci. Lab., Denison Univ.*, vol. xiii, p. 154, 1907.

ous tributaries, particularly those from the north. Just before the junction of the valley of the Raccoon with that of the Licking rivers another narrowing occurs. The relative widths and lengths of these described portions of the Raccoon may best be obtained by consulting the contour map, fig. 1.

Rock Floor. The entire length of the valley from Alexandria east to its junction with the Licking has been shown to be filled

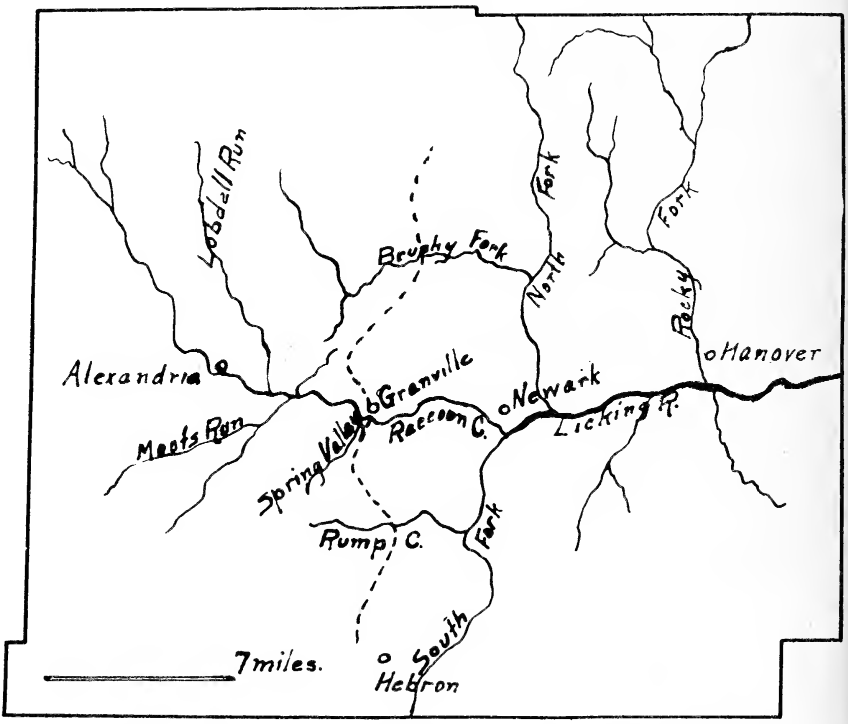

FIG. 1. Present drainage of Licking County. The broken line indicates a former divide.

with an enormous depth of glacial débris. On the Sinnett farm, about one-half mile east of Flower Pot hill, a drilling made in probably the middle of the valley discovered 274 feet of loose material overlying the rock floor. This added to the altitude of Flower Pot hill above the present valley bottom gives a total depth for the uncovered valley of over 325 feet. Subtracting the thickness of the unconsolidated material from the surface

altitude, the altitude above sea-level of the rock-bottom is here approximately 646 feet. The A. R. Wright well, located about five miles west, also in the valley bottom, has an altitude of 930 less 170, or 760 feet above sea level. The Colville well, three-fourths of a mile east of Alexandria and very close to the débris divide between the valleys of the Raccoon and Brushy Fork, has an altitude of 931 less 238 or 693 feet. While for the purpose of logical treatment it is desirable that all data should be

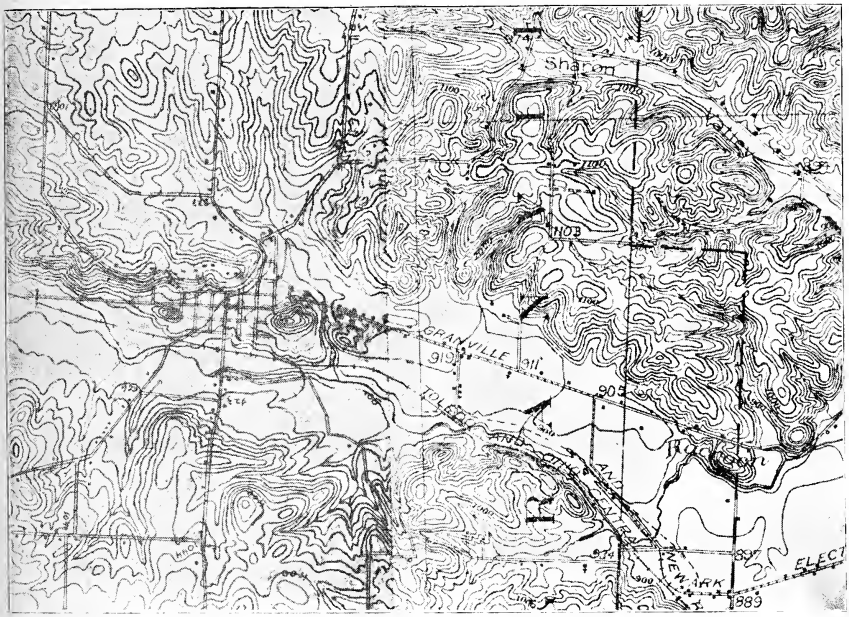

FIG. 2. Topography of the region about Granville, based on "advance copies" of the Newark and Granville sheets supplied by Mr. J. H. Jennings, Geographer, U. S. Geological Survey.

secured from corresponding points relative to the valley center, it is impossible to determine absolutely whether the data given conforms to this. Nevertheless it seems safe to conclude from all the drillings, including several in addition to those given above, that the altitude of the rock-bottom west of the Sinnett well gradually rises as it approaches Alexandria. The Colville drilling, though west of the Wright well, has a much lower rock bottom and probably lies near the center of the old Alexandria river.

The statements of drillers and managers indicate that most of the rock formations shown in the drillings are approximately uniform in thickness throughout the county; but they give varying statements for the "slate" (Berea[24] or Sunbury[25] Shale, probably including some Cuyahoga) found directly above the "Berea Sand," so-called by the drillers, and underlying the drift. Assuming that this "slate" when laid down conformed in this particular to the formations beneath, pre-Pleistocene erosion would be the natural cause of the present irregularity in thickness. By simple computation from records furnished, the Sinnett well is found to have a thickness of 184 feet of this uppermost formation, the A. R. Wright well 250 feet, and the Colville well 167 feet. The significance of this will be explained later.

All information obtained is uniform in supporting the theory that the strata dip east or southeast. One manager[26] stated that this dip equals thirty feet east per mile. Further computations from the three well records already quoted favor greater conservatism than this. The altitude of the upper surface of the "Berea Sand" (which it is assumed is uneroded and of uniform thickness in this area) is figured in the Sinnett well as 461 feet, in the Wright well 510 feet, and in the Colville well 526 feet. This dip, divided by the distance between the first and last, about 6 miles, gives an eastward slope of 19 feet per mile. The Black Hand Formation, the outcropping rock in this area, according to the measurements made by C. L. Herrick, and by Carney, shows a confirmatory dip. Herrick determined this dip near Granville to be 14 feet south and 18 feet east per mile. All the data[27] secured by him indicates the same general direction of dip for the other formations. Carney's work in Perry township shows a dip eastward of nearly 13 feet, and southward about 18 feet per mile.[28]

Tributaries. In the outlet portion of the Raccoon several tributaries break into the north wall. The largest of these occupied by Clear Run entering the Raccoon just east of Mount Parnassus, has extended its valley ramifications northwestward into the old divide. The principal tributary from the south has cut a deep

[24] E. Orton: *Geological Survey of Ohio*, vol. vi, p. 371, 1888.
[25] Chamberlin and Salisbury: *Geology*, vol. ii, p. 554, 1906.
[26] Fletcher S. Scott (private company), Newark, Ohio.
[27] *Bull. Sci. Lab., Denison Univ.*, vol. iii, pp. 24–5, 1888.
[28] *Ibid.*, vol. xiii, p. 120, 1906.

channelway almost parallel with the Raccoon into the first rock terrace, leaving it standing as a ridge merging into Flower Pot hill on the west. These streams generally head in circular-like valleys frequently wider than the lower portions, a character doubtless due to the fissile character of the lower rock in the valley walls.[29]

Of the tributaries to the wider portion of the Raccoon west of Granville, the one occupying an old wide valley to the south has been already mentioned. A small barbed tributary arising in the divide area is received from the north. Further west Lobdell Run from the north and Moots Run from the south are tributary.

In general the valleys tributary to the Raccoon show a contra-barbing to the east and west of the Granville col. Those to the east show a normal condition, i. e., the smaller angle made with the Raccoon points east. Those to the west show an abnormal tendency, i. e., the smaller angle points west or upstream relative to the present Raccoon. This contra-barbing is itself evidence of a drainage diversion: The tributaries to the lower end of the Raccoon conform to the normal tendency of tributaries in joining their trunk stream. When the abnormal is found, as west of the assumed former divide at Granville, the most satisfactory explanation is that at one time the present abnormal was normal, which in turn necessitates the hypothecation of an originally west flowing drainage at this point.

Incompetency of Glacial Explanation. The frequent obliterating effect of glaciers by masking the primitive topography with a mantle of drift makes absolute accuracy in the discussion of the preglacial histories of such areas practically impossible. Tight has favored glaciation as a cause of drainage changes[30] in central Ohio, although admitting without discussion the apparent preglacial origin of the lower end of the Raccoon and of the South Fork of the Licking. The glacial theory, if pertinent to this problem, presupposes an ice-mass coming from the west, ponding a body of water against the divide at Granville. This water would seek an outlet across this *S* divide toward Newark. The cutting of this divide could not be permitted, however, the entire length of Pleistocene time for completion, since the entire valley from

[29] F. Carney, *Ibid.*, p. 130.

[30] *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 37, 1894.

Alexandria to Newark has a deep filling of glacial débris, which as described by Tight[31] shows both Illinoian and Wisconsin characters. The presence of Illinoian drift east of the divide would indicate that if the col was cut glacially, it must have been completed during early Pleistocene times. "Spring Valley Stream,"[32] a tributary to the Raccoon, flowing laterally on the east wall of the "Old Valley" west of Flower Pot hill, could not have taken its original course[33] unless the divide had been previously removed. This again brings up the question of the competency of water deprived of its load to cut through such divides in the comparatively short time that may be granted.

To explain the capture at Granville the glacial theory would further require that the slope of the rock floor from Granville westward would be downward, and that this direction gave way to an eastward slope of débris because of the varying deposition of the latter. But the rock floor has been found by the drill records to slope eastward. This fact alone would seem sufficient to preclude any theory of capture due to glacial influences.

It may also be added that of all the cols noted in Licking county by the writer, none open toward the south. Many opportunities for the damming of water against east-west divides existed, while the direction of ice-movement further favored such phenomena. The persistent occurrence of these gaps opening toward the east does not seem in harmony with a glacial explanation.

Competency of Explanation by Diastrophism. That a divide formerly passed north and south through Granville is obvious from physiographic evidence. If further evidence in addition to what has been given were needed, the Sinnett and Colville wells in their order westward may again be cited: In the first there is a thickness of the Berea formation of 184 feet, in the second 167 feet. The Sinnett well is obviously near the valley center and consequently marks the point of greatest erosion in this immediate locality. The Colville well in the wider valley westward shows a greater erosion by 17 feet. This difference alone is an indication of a former west flowing drainage, assuming that the Berea was originally of equal thickness at both places.

[31] *Bull.. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 37, 1894.
[32] E. R. Scheffel: *Loc. cit.*, pp. 158–160.
[33] *Ibid.*, p. 165.

As the slope of the rock bottom of the Raccoon valley from Alexandria towards Newark is now eastward, land-movement can be the only remaining explanation for the reversal of drainage west of the divide at Granville. The dipping of the strata eastward may be even suggestive of tilting in that direction. (It is admitted that the A. R. Wright well shows some discrepancy with all but the last of these explanations, but its harmonism with the latter suggests that the disharmonism is due to its probable situation on the old valley wall rather than on the valley bottom.)

Confirmatory evidence from other streams.—*Brushy Fork.* The northern débris boundary of the wide Raccoon valley to the west of Granville, as already mentioned, forms a divide between this valley and a similar one occupied by the headwaters of Brushy Fork. From this wide headwater valley Brushy Fork flows eastward toward a narrow rock-walled channel. This channel reaches its narrowest portion about a mile farther east and then very slowly widens until its junction with the valley of the North Fork of the Licking. Glacial débris *in situ* lying against the valley wall with water-laid material above has been noted. In its wide drift filled headwater portion and its narrow rock-walled outlet portion it is strikingly similar to the valley of the Raccoon. Throughout its length it is about parallel to the latter stream. In a north-south direction the narrowest portion of its valley would fall in approximate line with the narrowest portion of the valley of the Raccoon at Granville, the latter constriction representing the capture of a west flowing stream formerly tributary to the Alexandria river, which in turn was captured by the Brushy Fork.

Rump Creek. This stream is the next south of the Raccoon, flowing nearly parallel to it and emptying into the South Fork of the Licking river. Its valley shows a decided widening toward the west and narrowing toward the east similar to the condition noticed in the Raccoon and Brushy Fork valleys, with the greatest constriction in the same approximately north-south line. The length of the narrow portion is, however, much shorter than the other streams, this being due to the swinging southwest at this point of the South Fork of the Licking to which it is tributary, by which its eastward extension is cut off. No well data was obtainable in this area. The physiographic evidence makes it not unreasonable to suppose that glaciation may have been responsible for the capture, but the theory of land-movement is equally as reasonable.

The Licking Rivers. Both the North and South Forks of the Licking river occupy in their lower ends mature valleys well filled with débris. In the northern part of the county the North Fork turns sharply to the west, this portion formerly draining, according to Tight, directly to the Scioto System. At Newark the aggraded material reaches a maximum depth of 300 feet. This gives an altitude (above sea level) for the rock floor of about 500 feet.[34] Toward the southern part of the county near Hebron the valley, though continuing very wide, becomes drift-choked. Drillings, one showing a drift filling of 341 feet in Liberty township, Fairfield county, strongly support Tight's theory[35] that this valley was formerly continuous southwestward to the old Scioto drainage. It is noted west of Hebron also that the coarse sandstone capping the valley walls has been eroded much more than its equivalent the glass sand[36] formation, constituting the walls of the east-flowing Licking of which the South Fork is a branch. The inference is that the present most southerly portion of the South Fork must represent an older active drainage than that of the present east-flowing Licking. At the present time the South Fork of the Licking turns, just south of the county line, sharply north and west for its headwater drainage, becoming approximately parallel with the east-flowing streams before mentioned. The entire drainage of the North and South Forks and the Raccoon meets at Newark, passing eastward through a gorge-like valley narrower than the lower portion of any of these tributary valleys. This east-flowing stream, the Licking river, which receives nearly all the eastern drainage of the county, also, after a turn southeast, empties into the Muskingum river at Zanesville, and thence its waters pass southeastward to the Ohio river.

In the Licking System two points particularly may be noted:

1. The long tributary streams come from the north and west. These are, following to the left a circle including all the more important, the Rocky Fork, the North Fork of the Licking, the Raccoon, and in general direction the South Fork of the Licking. Such an arrangement would result, according to Campbell's theory, from a differential tilting toward the northwest or a differ-

[34] W. G. Tight: *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 36, 1894.

[35] *Ibid.*, p. 37.

[36] F. Carney and A. M. Brumback: *Ohio Naturalist*, vol. viii, pp. 357–60, 1908.

ential subsidence toward the southeast. "Tight has shown that the greater part of the Muskingum drainage system was formerly connected with the Scioto system by a broad valley leading from Dresden (a few miles above Zanesville) westward past Newark to the Licking reservoir, and thence into the Scioto basin near Circleville.[37] The present southward course past Zanesville is through a much narrower valley than the old line leading westward to the Scioto Basin, and the rock floor is markedly higher along the present course of the Muskingum than along the old course."[38] This old connecting drainage line Tight has named the "Newark river."[39] Besides carrying the old Muskingum drainage it received some of the streams now tributary to the Licking.

2. The east bank of the old Newark river so far as observed from Hanover to the Licking reservoir about 10 miles southward is abnormally steep considering the width of the valley. On the assumption that tilting has taken place this would be explained by an axis of uplift, approximately parallel to the valley, on the further side, or a corresponding depression on the near side. Under such conditions streams perpendicular to the axis also work headward and may finally capture the parallel streams.[40] The time required would depend on the vigor of the movement and the degree of intrenchment of the parallel stream sought for. With the case in point it is conceivable that an enormous period of time, representing a probably very slow movement must have been required for this diversion. While the old Muskingum was slowly reaching back through its tributaries to the old Newark valley, the drainage of the latter was in turn under cutting its left bank in an endeavor to escape eastward.

Conclusions. It appears from the evidence that formerly the drainage of the western part of Licking county passed directly to the valley now occupied by the Scioto System from the present headwater areas of the Brushy Fork, Raccoon creek and the North and South Forks of the Licking. The present lower portions of the same streams and also Rocky Fork (together, perhaps, with glacially obliterated streams from the south) drained into the same

[37] *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, pp. 35–61, 1894.
[38] F. Leverett: *Monograph* xli, p. 155.
[39] U. S. Geological Survey, *Professional Paper* no. 13, plate i, 1903.
[40] M. R. Campbell: *Journal of Geology*, vol. iv, pp. 658–9, 1896.

old system through the former Newark river, having a general direction of west-southwest. Later all this drainage was diverted eastward through the present Licking valley.

No doubt has been expressed by any writer concerning the actual occurrence of the captures indicated. The general tendency, however, has been to refer them to glacial causes. Hints that differential movement may have been a factor have been given, but nothing has been adduced to support such a theory. The purpose of this paper has been to emphasize the possibility that this may have been the controlling factor even before glacial times, aided also by the stratigraphy which in at least part of the divide area permits rapid weathering. While arguments are available in favor of the glacial theory, yet in view of the fact that all the changes conform to the theoretical results following a simple differential movement of uplift or subsidence, it would seem that the latter factor should be given a more serious consideration than it has been accorded.

While the problem has been treated from a localized standpoint, a study of Tight's map[41] shows similar drainage changes over almost the whole of Ohio, including the drainage under discussion. Formerly this combined drainage passed northwest, now it passes southeast. May not the same cause have been operative in both instances causing the reversions; and may not the theory of differential movement be perhaps nearer the truth than the glacial?

PENEPLANATION

The hills of the western part of the county consist of rock of the Waverly Series. Tight in discussing the Muskingum area gives the Cretaceous as the probable period of base-leveling.[42] This time would also seem applicable to the Licking county area, though a later date is not improbable. If this supposition is correct then if these drainage changes were caused by differential movement this movement must have come between Cretaceous and Pleistocene times. Attempts have been made to correlate the rock formations of this area with those in the Allegheny Plateau

[41] *Professional Paper* no. 13, plate i.
[42] *Bull. Sci. Lab., Denison Univ.*, vol. viii, pt. ii, p. 55, 1894.

region. Differences of opinion have resulted,[43] but the areas have generally been accorded the same period (Cretaceous) of peneplanation.[44] Oscillations of the earth's surface have been evidenced in the Great Lakes area and in the Allegheny Plateau region.[45] The probability that the Ohio area under discussion has been genetically connected with some of these movements seems plausible.[46]

SUMMARY

1. This article has endeavored to throw some light on the subject of drainage changes near Granville, Ohio, first giving a brief of the general subject—drainage changes—in which the three principal causes are discussed: piracy, glaciation, and diastrophism.

2. The wide headwater and narrower outlet portions of the streams tributary to the North and South Forks of the Licking are evidence of a diversion to the east. The narrow outlet of the combined drainage through the Licking Narrows east of Newark further supports such a contention.

3. The commonly ascribed causes for such drainage changes in Ohio are not competent because: (*a*) So many similar phenomena are hardly consistent with a glacial cause. (*b*) Overflow streams would not be competent, in the times which may be granted, to do the enormous amount of cutting represented. (*c*) The eastward slope of the eroded rock floor, as illustrated in the Raccoon, strongly derogates against such a theory.

4. The reasons proving a diversion of drainage and those opposing a glacial explanation for such diversion, support, in general, the theory of diversion by tilting.

5. By differential land movement (probably in late Cretaceous times or possibly as late as the Pliocene) the drainage of Licking county has been diverted from the Old Scioto System west of Lick-

[43] C. L. Herrick: *American Geologist*, vol. iii, p. 95, 1889. C. L. Herrick: *Geol. Surv. of Ohio*, vol. vii, pp. 409, 501, 1893.

[44] W. M. Davis: *Bull. Geol. Soc. Am.*, vol. ii, p. 561, 1901. M. R. Campbell finds evidence of two peneplains in same area. See *Bull. Geol. Soc. Am.*, vol. xiv, pp. 277–96, 1903.

[45] F. Carney: *Am. Jour. of Sci.*, vol. xxiii, p. 326, 1907.

[46] F. Leverett: *Journal of Geology*, vol. iii, p. 763, 1895.

ing county to the southeast flowing Muskingum lying east of the same county.

6. If Point 5 is correct, then such an explanation rather than glacial may apply to most of the drainage changes of Ohio.

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June, 1908.

THE AGE OF THE LICKING NARROWS AT BLACK HAND, OHIO.[1]

KIRTLEY F. MATHER.

The Licking river is formed at Newark, Ohio, by the confluence of three streams, the North and South Forks, and Raccoon creek. Thence it flows almost due east and joins the Muskingum at Zanesville. Newark lies in the center of a broad open valley, partly filled with glacial drift, at the head of the Licking river. At Claylick, seven miles downstream from Newark, the Licking river leaves this broad old valley and continues eastward in a narrow channel which, a mile and a half farther on, becomes a gorge, cut 90 feet deep, in the Black Hand formation. The walls rise perpendicularly from the stream's edge and there is scarcely room for the railroad tracks on either side. The river winds through this gorge for a distance of two and a half miles, and at Toboso the valley widens out again to about half the width of the first valley at Newark.

The older and broader Newark valley continues from the vicinity of Claylick northeastward toward Dresden, but at Hanover is nearly filled with glacial drift. The rock topography of the region makes it apparent that in pre-glacial times this valley was occupied by a stream flowing southwestward, and tributary to the ancient Scioto. This stream has been named the Newark river, and it has already been pointed out that it must have been captured and diverted by the present east-flowing Licking.[2] The simplest hypothesis to account for this piracy would be that when the ice sheet, classified by Leverett[3] as Illinoian, entered this region it acted as a dam across the channel of the west-flowing

[1] This paper is the result of investigations undertaken, as a partial requirement for a Master's Degree, under the direction of Prof. Frank Carney of Denison University, and was read before the Ohio Academy of Science, November 28, 1908.

[2] Tight: *Bull. Sci. Lab., Denison Univ.*, vol. vii, part ii, p. 49, 1894.
Leverett: U. S. Geological Survey, *Monograph* xli, p. 155, 1902.

[3] *Ibid.*, p. 51.

stream causing its waters to back up into a lake, which, overflowing across the divide into a tributary to the Muskingum, would cut down the channel at the Licking Narrows.

Under this theory the present terraces in the valleys of the Licking and its tributaries would be deposits formed in the waters of this one large lake. Moreover, the drift which fills the Newark valley for a distance of three or four miles east of the Hanover dam would be in the nature of subaqueous outwash. It has already been shown[4] that this drift-filling is a deposit from a valley dependency of ice extending as far as the drift is found.

It is the purpose of this paper to show that a similar dependency stretched out down the Licking valley past Claylick, that no large lake occupied the valley at this point, and that the last capture and reversal of drainage in the Newark valley was accomplished before the invasion of the ice sheet.

The glaciation of the region. The ice of the Illinoian glacial stage entered this region from the west, and its frontal position was that of an irregular line drawn north and south through Claylick. At the time of the ice-advance the region was maturely dissected and the topography had a great influence on the work of the glacier.[5] In the valleys, tongues of ice extended for some distance in front of the main lobe while on the highlands the advance was retarded. Valley trains of sands and gravels stretch down the stream channels away from the ice-front.

It is quite difficult to map the exact limit of the ice as there are no topographic features, such as a terminal moraine, to help in the work, and because there was so much fluvio-glacial action which carried drift far beyond the edge of the ice.

The valley terraces. Between Claylick and the Narrows, the Licking river has four tributaries which join it from the south; these are designated *A*, *B*, *C* and *D* (fig. 1).[6] The first three of these streams flow in relatively broad valleys somewhat filled with drift. One of the most striking characteristics of these northward trending valleys is the persistent terrace which is found in each

[4] Carney: *Bull. Sci. Lab. Denison Univ.*, "The Glacial Dam at Hanover," vol. xiii, pp. 139–153, 1907.

[5] Leverett: *Loc. cit.*, p. 222.

[6] I am obligated to Mr. J. H. Jennings and to Mr. W. H. Herron, geographers of the U. S. Geological Survey, for an advance sketch of this portion of the Newark and Frazeysburg topographic sheets.

one. A detailed description of this feature in valley *A* will be typical of all three. Here the terrace is so persistent that it is impossible to climb from the stream bed to either divide without crossing it. It has a down stream slope of six or eight feet to the mile, but, as the gradient of the stream is several times as great, the top of the terrace is only fifteen feet above the bed of the brook at the south, while it is thirty-five feet above it at the northern end. The terrace is also slightly higher on the west than on the

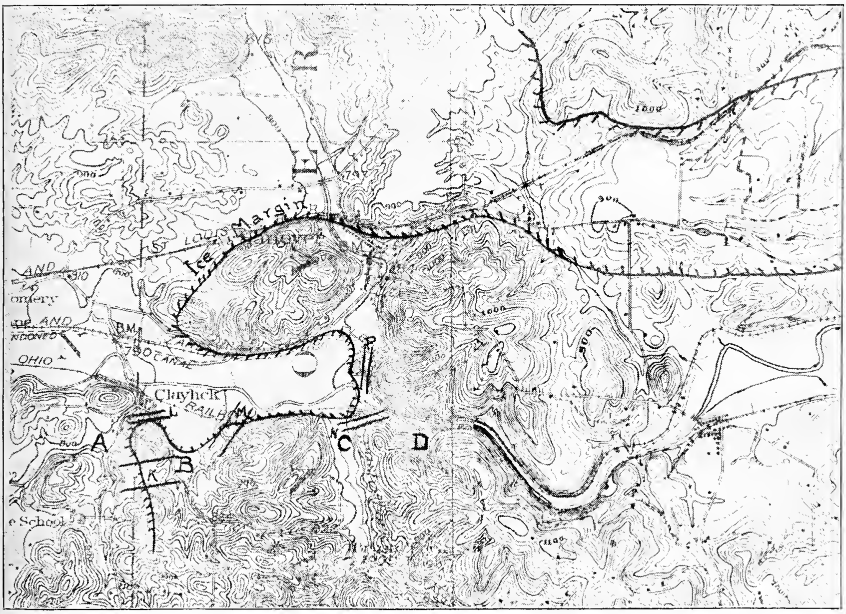

Fig. 1. Map of the Licking Narrows area. From the Newark and Frazeysburg Quadrangles, advance sheets, U. S. Geological Survey.

east; the combination of these two gradients is such that the lowest point in the terrace is just as high as the lowest point in the valley wall, at *K*.

The terrace is composed of fine sands, clays, and gravels, and varies in its composition in different places. At its northern end a gully cut in it reveals a section consisting of clay interbedded with fine loess-like sands. These sands are entirely free of gravels and have no distinct stratification or lamination. The clay beds are from two inches to nearly a foot in thickness and some of them

are quite persistent, though they are seldom horizontal. The upper foot or foot and a half of the terrace is here composed of waterworked gravels and small bowlders of foreign rock, evidently of fluvio-glacial origin.

A quarter of a mile farther up-stream, the terrace is thirty feet above the stream bed and here sands have been removed for molding purposes. The surface is covered by rubble and débris up to sixteen feet above the stream bed, but above this point a good section is exposed. At the base (fig. 2) is a fine gray sand with an intricate crossbedded and laminated structure. Two feet higher the sand becomes yellowish and clayey; the length of the ripples is nearly double the length of those below and the sand is finer and retains its shape when molded in the hand. The fine laminæ are accentuated by reddish, oxidized streaks, found only in this yellowish bed. This must mean that the oxidation took place during the deposition of the sand for only in that way could the lines of oxidation coincide with the lines of deposition. This deposit is five feet thick, and above it there is five feet of light yellow sand. The latter has occasional streaks of the gray sand found at the base of the section, but has nothing of the clayey character of the sands directly beneath it. This bed is about the same in texture as that at the base and has the same stratification and lamination. The three beds of sand grade into each other, are loess-like, and contain only an occasional small pebble and no shells. The remaining three feet of the terrace above them consists of gravels quite sharply separated from the sands beneath by a nearly horizontal plane, and quite evidently of glacial or fluvio-glacial origin.

Directly across the valley to the west of this section there is another place where sand has been carted away. The deposit here is similar to that in the upper and lower beds of the section just described. The cross-bedded structure is the same and its tendency to stand in vertical or even overhanging faces is also apparent. The upper surface of this deposit is ten to twelve feet above the surface of the terrace. It seems to fill the angle between the valley wall and the terrace surface and slopes upwards against the former. The whole deposit has the appearance of a fan spreading out from halfway up the valley wall and sloping down to the terrace level where it flattens out into the broad terrace.

These fine sands in the composition of the terraces in the three

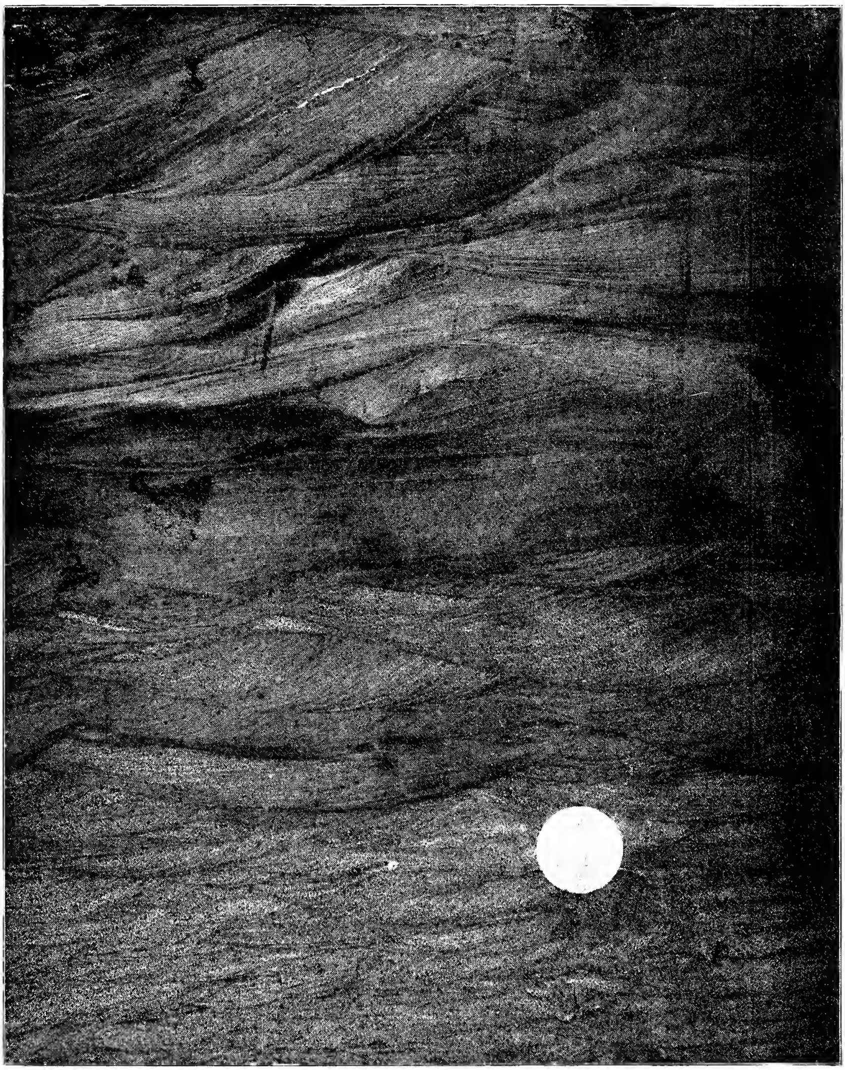

Fig. 2. Cross-bedded stratification of terrace in valley "A," near Claylick, Ohio.

valleys are only found in a few localities and are not a general feature of the terrace structure. As a rule the terraces are made up of stratified and cross-bedded gravels, clays, and sands, alternating locally with areas of unstratified gravels. They present all the appearance of fluvio-glacial deposits made in a ponded or very sluggish stream containing unstable currents overloaded with material from the melting ice. This same conclusion is reached in a consideration of a similar deposit at Andover, Mass.[7] A photograph of the delta-plain material at that place presents an appearance very similar to that described in these terraces.

The terrace in valley *A* extends across the divide through the channel *K* into valley *B*. Here the same persistent terrace is found at a corresponding level. It sustains a similar relation to the brook as does the terrace in the first valley except that here there has been a little more erosion since its formation. This, however, is not antagonistic to the idea that the two terraces were formed at the same time in the same body of water because tributary *A* has been held up by a rock barrier near its confluence with the Licking while stream *B* everywhere flows on a till floor.

In valley *C* the same sort of a terrace, composed of similar materials, is found on both sides of the valley. At first inspection it appeared to be about the same elevation as the terraces in the other two valleys but when the topographical map of the region was obtained it became evident that here there was a discrepancy. The elevation of the terraces in valleys *A* and *B* is 830 feet while that in valley *C* is only 810 feet above sea level. The necessity of attributing these terraces to lacustrine deposition is here accentuated by the fact that at the southern end of the valley, where two smaller streams converge to form the tributary *C*, there are found delta-like deposits at the mouths of each of the small brooks. These delta-fans are the result of deposition, at the time that the lake occupied the valley, of the material brought to the lake by these two small streams.

It was pointed out that these terraces all contained assorted glacial drift, but in valley *D* no terrace nor glacial drift was discovered. This last valley, although younger and smaller than any of the three others, is of pre-glacial age. It is, also, broad enough to favor the formation and preservation of this same sort of terrace if glacial waters had been ponded in it.

[7] F. S. Mills: *American Geologist*, vol. xxxii, pp. 162–170, 1903.

From these facts it follows that the relation of the ice-sheet to the topography must have been such that the outflowing waters were ponded in valleys *A* and *B* at one level, in valley *C* at a different level, and were not ponded at all in valley *D*.

Old water channels. Three-fourths of a mile south of Claylick there is a broad sag (Channel *K*, fig. 1) connecting valleys *A* and *B* at the level of the terraces described above. The terrace in valley *A* is slightly higher than that in valley *B* and slopes gently eastward through this sag into the latter valley and is continuous

FIG. 3. Bench "L," near Claylick, Ohio.

with the terrace there. That this sag was the outlet of the lake in valley *A* at the time of the formation of the terrace system is evident.

The cemetery of the town of Claylick is situated on the bench marked *L* (fig. 1) and shown in the photograph (fig. 3). It must have been carved out of the hill slope by the overflow of the lake in valley *A*, which at some time evidently flowed across it. This course must have been taken by the stream after its diversion from the sag *K*, but before the complete withdrawal of the ice, whose front must have served as one side of the outflow channel at *L*. After the retreat of the ice sheet from that point the stream slipped off this bench and its course can be seen in a broad curve in the

foreground of the photograph; this curve marks the level where it paused for a time in the relatively rapid cutting of its channel in the unconsolidated glacial drift. A diagrammatic profile of this bench is shown in fig. 4.

Nearly a mile east of Claylick, at the point *M*, there is a much larger bench whose level coincides with that of the terrace in valley *B*, and is five feet lower in elevation than the sag *K*. The terrace can be traced around the valley, sloping gently from the sag to the bench. This bench was carved in the slope of the valley wall at this point, where there must have been a spur extending in a northwest direction into the valley. Almost in the center of

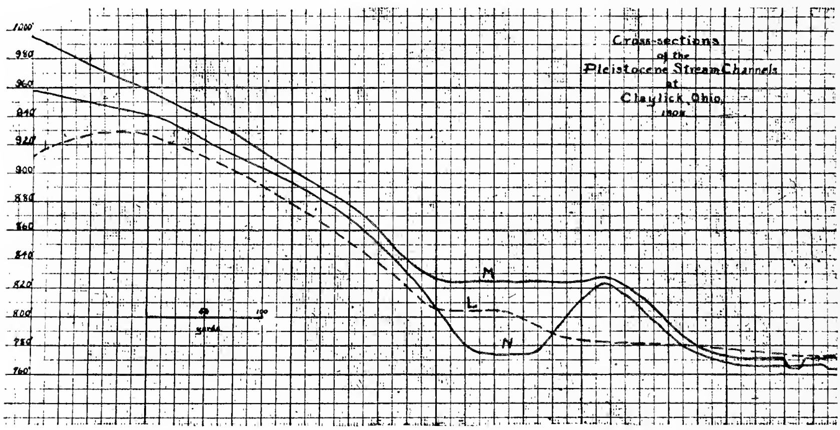

Fig. 4. Diagrammatic profiles of abandoned stream channels near Claylick, Ohio.

the bench a well has been sunk to a depth of sixty feet. It passes through ten feet of sand and gravel before it reaches the underlying rock which outcrops on the hillslope adjoining the bench on the east. At the western end of the bench there is a slight elevation of two to three feet, formed by an outcropping knoll of the same bed-rock. This gives the bench a profile as shown in fig. 4.

It is evident that at the time the terraces were formed the drainage from valley *B* flowed across this bench, producing its present shape. To do this the lateral stream from the glacier must have been held against the valley wall by the front of the ice.

Two miles east of Claylick, just at the entrance to the Licking Narrows, there are two more abandoned channels which were

carved by the glacial waters. (Channels *N* and *P*, fig. 1.) Channel *N* presents a profile as shown in the diagram, fig. 4. Its floor is continuous with the terrace on the adjacent valley slope and is covered with a thin deposit of sand and gravels, much waterworn, and underlain by the rock in place. That the tributary in valley *C* flowed through this channel at the time of the formation of the persistent terrace is quite evident. Since Pleistocene times it has reverted to its pre-glacial channel where it now flows on gravels ten feet below the level of the bed-rock in the old channel.

Channel *P*, across the Licking, shows similar structure and history; the origin of the two channels must have been the same. The only explanation that satisfactorily accounts for the carving out of these channels on the slopes of hills is that the ice-front abutted against them and served as one of the valley walls until the stream was well established in its new course.

The frontal limit of the ice sheet is, then, definitely located in these four places by the channels which resulted from its position. It is necessary, therefore, for us to postulate a valley dependency similar to, though smaller than, the one in the old Newark valley[8] extending, as shown in fig. 1, down the Licking valley until it was stopped by the steep slopes at the points *M*, *N* and *P*. Glacial bowlders have been found near the top of the hill just south of Claylick; this fact, combined with the small amount of cutting necessary to carve the bench at *L*, leads one to suppose that the latter was covered by the advance of the ice and was formed during a retreatal pause of the ice-front.

The capture of the Licking. The hypothesis has been published that "after the retreat of the ice the Licking Basin was closed and as the waters rose in Lake Licking they reached a low col in the divide a little south of Hanover. The position of this col is represented by the present Licking "Narrows."[9] If this were the case terraces would be found in all four tributary valleys at the same elevation, for they would all be parts of the same lake. As stated above there is a marked discrepancy between the elevations of those in valleys *B* and *C*, while no terrace, or signs of a glacial lake, is found in valley *D*. The phenomena of the region do not, therefore, coincide with this hypothesis.

[8] Carney: *loc. cit.*, p. 149.

[9] Tight: *loc. cit.*, p. 49.

Moreover, the sag at *K*, the bench at *M*, and the channel at *N*. could not have been formed if the large valley had been occupied by a lake at that time. They must be the work of lateral drainage between the front of the ice and the adjacent hill-sides. This stream, and the rest of the water from the melting ice must have had an unobstructed passage out of the valley, which, as has been shown, was occupied by the valley dependency. This outlet could only have been through the present Licking Narrows. This necessitates the placing of the capture of the Newark river by the Licking in pre-glacial times.

Under this hypothesis the difficulties at once vanish and all the phenomena of the region are satisfactorily accounted for. The tongue of ice occupying the larger valley would have formed a dam across the mouths of the tributaries *A*, *B* and *C*, and would have caused a lake to form in each of them. The connection across the sag *K* would have made the body of water continuous in valleys *A* and *B* and accounts for the correspondence between the elevations of the terraces in them. In valley *C* the water would probably stand at a different level and this corresponds with the observations of the heights of the present terraces. In fact, this is the only hypothesis that can correspond with the phenomena and account for two different lakes at different levels in valleys *B* and *C*, and at the same time allow valley *D* to remain without fluvio-glacial deposits.

The waters from the lake in valley *A* at first overflowed across the sag *K* into valley *B*. Here the water level rose until it reached the lowest place of exit, where the ice front abutted the flank of the hill at *M*. The channel was gradually cut down until it formed the present bench. The stream of glacial waters flowing along the face of the cliff from tributary *B* to valley *C*, between it and the ice front, has left faint traces of the work of degradation in the slope of the profile. This stream, reinforced by the waters of the lake in tributary *C*, cut, at the point *N*, the same sort of a bench as now exists at *M*. The stream here was much stronger than at the latter place, and the channel was cut much deeper.

When the stream at *M* reached the level of the present bench a slight retreat of the ice occurred. This opened up the channel at *L* and separated the lake of valley *A* from that of valley *B*. The waters of the former then flowed across the bench at that point and carved it in the same manner as that already described

at *M*. This also accounts for the secondary level of terraces found in valley *A* at this elevation.

At the same time the lateral drainage from the ice was concentrated in a channel between the ice-front and the face of the steep hill due west of Claylick. This accounts for the steepening of the slope near the base of the hill as shown in fig. 5. The same slight retreat of the ice-front permitted the stream flowing over the bench at *M* to slip down off from it and occupy the natural channel

FIG. 5. View looking west from Claylick, Ohio. The steepened slope near the base is due to marginal glacial drainage.

between the glacier and the base of the slope; thus a similar steepening of the slope at this point was produced. The channel at *N*, before this oscillation, had become so firmly established that it retained its stream of water until the abnormal conditions due to the presence of the ice had been entirely dissipated. Then, a small stream working in the soft gravels, north of the outlier produced by *N*, captured and deflected the creek from its rock channel. This piracy can still be traced in detail in the former courses of the creek and its small branches.

Across the valley northeast of Claylick, the steepening of the base of the southern slope of the hills is indicative of similar glacial stream action between the ice-front and the valley wall. The village of Hanover is in a valley which, at the maximum extension of the ice, must have been occupied by a glacial lake, as shown by the terraces found here at an elevation of 800 feet. This lake was held up by the ice of two dependencies of the main sheet, one at either end of the valley. Its overflow and subsequent drainage conditions account for the channel at *P*, now occupied by the traction line and the old canal; this channel is similar in every way to the one at *N*, already described, and must have had a similar history.

An alternate hypothesis. It has been hypothecated that when the glacier advanced into the valley past Claylick the ice-front drainage would have had unusual erosive powers and might have channelled the divide area so rapidly that a lake condition did not exist long. It, however, is not conceivable that an ice-front stream would have been strong enough to cut a channel in the Black Hand formation a mile and a half long across a ninety foot divide without necessitating the ponding of the stream between the ice-front and the crest of the divide. The large amount of cutting necessary in the development of this channel, therefore, precludes the possibility of its having been made during the advance of the ice into the valley.

The cause of the capture and reversal. The capture of the west-flowing drainage by the east-flowing Licking immediately preceding the glaciation of this region—perhaps in the earliest stages of the Pleistocene period—is not discordant with our knowledge of conditions at that time. The close of the Pliocene is looked upon as a time of crustal movement, a critical period in the history of North America. Streams were turned from their courses in some places and nearly everywhere started on careers of increased activity.[10] A slight differential tilting would have caused the Muskingum and its tributaries to increase their valley cutting, and the reversal of drainage would have followed as the result of stream adjustment. The gorge of the Narrows is located at one side of a broad open valley having a lateral extension to the north of the crest of the gorge walls; this mature valley, at this point, was cut

[10] Chamberlin and Salisbury: *Geology*, vol. iii, p. 316, 1906.

down to the surface of the Black Hand formation, and it seems likely that its stream was flowing at this level when its action was increased by the tilting, probably near the close of the Pliocene, and the gorge started to develop in the bottom of the valley. As soon as this gorge had been cut back to where it could tap a tributary of the west-flowing drainage system, stream reversal commenced in the Scioto system. This was a slow process, and how far it had reached before the ice invasion is not known. The difficulties of working out these details are many, because the changes were greatly complicated by glaciation which soon followed the adjustments started by the differential tilting.

These discrepancies between the phenomena of the region and the hypothesis that the reversal of drainage was due to glaciation, together with the accordance of the phenomena with the theory of pre-glacial capture due to differential tilting, lead us to the conclusion that the Licking Narrows at Black Hand, Ohio, are of pre-glacial age.

Geological Department,
Denison University,
December, 1908

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Permanent Secretary Denison Scientific Association

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A SPECTROMETER FOR ELECTROMAGNETIC RADIATION.[1]

A. D. Cole

At various times for some years the author has carried on experimental studies of electric radiation, measuring the amounts reflected, transmitted, absorbed, refracted and diffracted under different conditions.[2] For these purposes the separate pieces of apparatus were brought into suitable relation to one another by temporary mountings, somewhat deficient in accuracy and in convenience. Such makeshift arrangements have been common with most workers in this field. This is perhaps due to the influence of the classic pioneer work of Hertz[3] in 1888. In his case such arrangements were necessary because the long wave-lengths he used required apparatus of large size, which was, therefore, heavy and inconvenient. So its different parts were mounted and moved as separate units. Righi,[4] however in the early nineties showed how it is possible to obtain strong electrical radiation whose wave-length does not exceed a few centimeters, so that it then became possible to use apparatus of much more convenient dimensions.

There was a three-fold reason for the design of the apparatus about to be described. The first was the need of a more compact and easily adjustable mounting for the various pieces of apparatus used in continuing a research on diffraction phenomena, upon which a preliminary report was presented at the New York meeting of the A.A.A.S. The second reason was the desire to have a compact arrangement by means of which advanced students could repeat the experiments of Hertz, Righi, Boltzmann and others.

[1] Read before A.A.A.S., Section B. and the American Physical Society, December 31, 1908.

[2] A. D. Cole, *Wied. Ann.*, vol. 57, p. 290, '96—*Phys. Rev.*, 4, p. 50 '96– *Elec. World*, September, '96. *Phys. Rev.*, 7, p. 225; *ibid.*, 20, p. 268, '05 *ibid.*, 23, p. 238, '06.

[3] H. Hertz, *Wied Ann.*, 36, p. 769, or *Phil. Mag.*, 5, 27, p. 369.

[4] A. Righi, *Rend. Lincei.* 1893. p. 333.

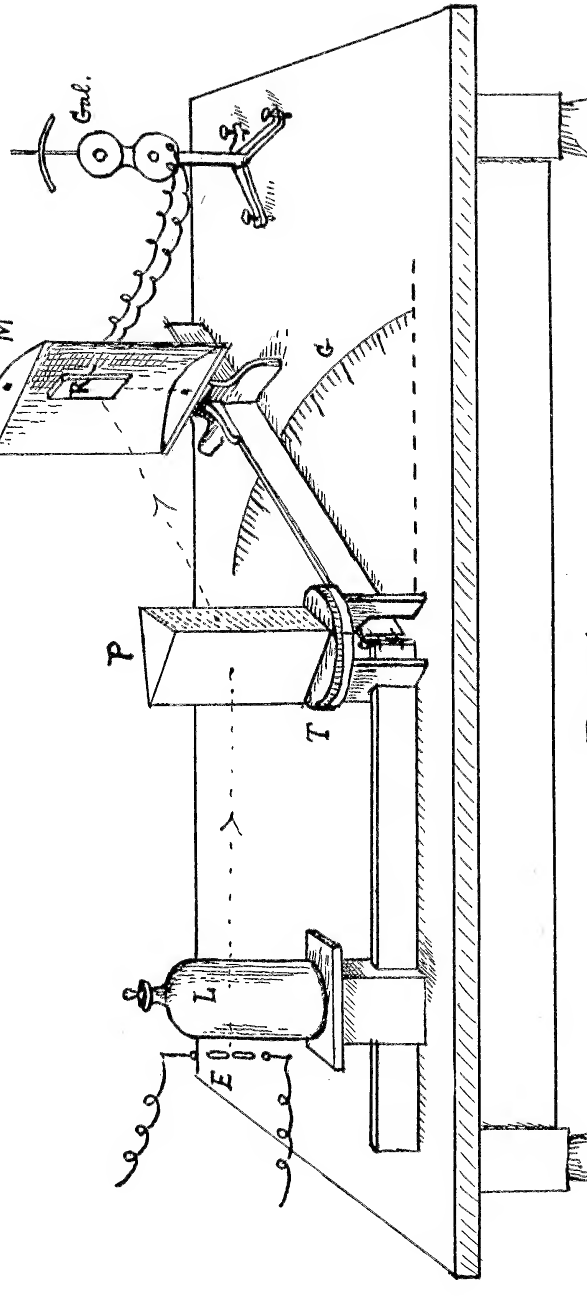


Fig. 1.

The third object was to secure the means of demonstrating the optical analogies of electric waves as completely and rapidly as possible in the lecture room.

It seemed that all three of these objects would be best attained by the use of a mounting for the several parts of the wave apparatus similar to a laboratory spectrometer for light. Such a design has indeed been used by Righi.[5] His apparatus, however, was only roughly quantitative and its indications could be seen by but a single observer at once. Furthermore, it was clumsy and lacked rigidity.

In the present design, an attempt has been made to secure a form sufficiently elastic to adapt it to a wider variety of uses than that of either Hertz, Righi or Lodge,[6] and so develop very completely the analogy bet een electrical radiation and light.

The apparatus consists of a suitable mounting for an exciter or generator of electrical waves and a similar mounting for the receiver. Each of these is supported by a moveable arm, swinging horizontally about a common vertical axis which is also the axis of a revolving central table. Upon this a prism, grating, diffraction slit or other optical device can be placed. The exciter and receiver are as a rule each mounted in the focal axis of a cylindrical parabolic mirror, as in the original experiments of Hertz. Either or both of these converging mirrors however can be replaced by a cylindrical lens. An ordinary 5-lb. acid bottle filled with kerosene, benzine or gasoline makes a satisfactory concentrating lens. If the exciter is placed about 1.5 cm. behind it, the conditions for a "parallel beam" are secured. The illustration, (fig. 1) shows the exciter mounted at E behind the lens L and the receiver R (enclosed in a small pasteboard box) at the focus of the parabolic mirror M. A prism P is placed upon the revolving table T so as to receive the radiation concentrated by L and refract it to the receiver. The exciter is shown only diagrammatically in the figure. It is a modified Righi exciter consisting of two small cylinders with rounded ends, separated by an oil-filled spark-gap. A continuous flow of kerosene oil passes through this spark-gap. This exciter has been described by the author in *Phys. Rev.*, vol. 23, p. 241, (Sept., '06). [Some features of it have

[5] A. Righi, *Die Optik der Electrischen Schwingungen*, p. 9.

[6] O. Lodge, *The Work of Hertz and Some of His Successors*, p. 33.

been described more fully in an earlier paper in the same journal, *Phys. Rev.*, vol. 7, p. 226 (Nov., '98)]. The receiver used is a Klemencic thermo-junction made of fine iron and constantin wires. An early form is described in *Phys. Rev.*, vol. 4, p. 54 (July '96) and the form lately used in *Phys. Rev.*, vol. 20, p. 268 (April '05). This receiver is used in connection with a low-resistance Kelvin galvanometer of fairly high sensitiveness. The receiver is tuned to the period of the exciter by use of little sliding tubes as described in *Phys. Rev.*, 20, p. 269. Hertz used a receiver whose natural period was longer than that of his exciter and Righi one of shorter period than that of his exciter, but there are some advantages in having both of the same period.

To avoid confusion in the figure, some details of the apparatus are not shown. For instance, each of the parabolic mirrors is actually mounted so that it may be revolved about a horizontal axis *aR*. Thus the focal axis of each can be made horizontal or vertical, or may be set at any desired angle to that of the other, the angular position of each being read on its graduated circle. A third graduated arc *G* shows the angle which the two revolving arms, carrying exciter and receiver, make with each other. A fourth graduated circle *T* shows the angle through which the prism table is turned.

To keep the apparatus of convenient dimensions a wave-length of 10 to 15 cm. is used. This enables good results to be obtained with apparatus of moderate dimensions. For example, the aperture of the parabolic mirrors is about 35 × 33 cm., the two revolving arms are one 100 cm. and the other 120 cm., the prism-table 26 cm. in diameter, prism and lenses 22 cm. high, plane mirrors 30 cm., square, etc. In contrast with these dimensions Hertz's mirrors were of 200 × 120 cm. aperture, his gratings and his smallest plane mirror each 200 × 200 cm.; his prism was 150 cm. high and weighed more than 1300 pounds.

To illustrate the use of the apparatus a brief account follows of the method of performing some of the classic experiments of Hertz and others who have since brought the optical analogies of electrical radiation to convincing completeness. (1) *Proof of the existence of stationary waves by interference of direct radiation with that reflected by a plane surface.* The disposition of apparatus is shown in Fig. 2a. The exciter *E*, mounted in its cylindrical mirror, radiates toward the receiver *R* and the plane mirror *M*

placed immediately behind it. The radiation directly received at R interferes with that reflected from M. By shifting M back about 2 cm. at a time the phase relation of the two waves is changed and a system of nodes and loops obtained. In Hertz's original experiment a mirror 13 feet high was used; with our apparatus we commonly use one about one foot square. Fig. 3 shows the results of such an experiment with a mirror only 4 inches square. Distances

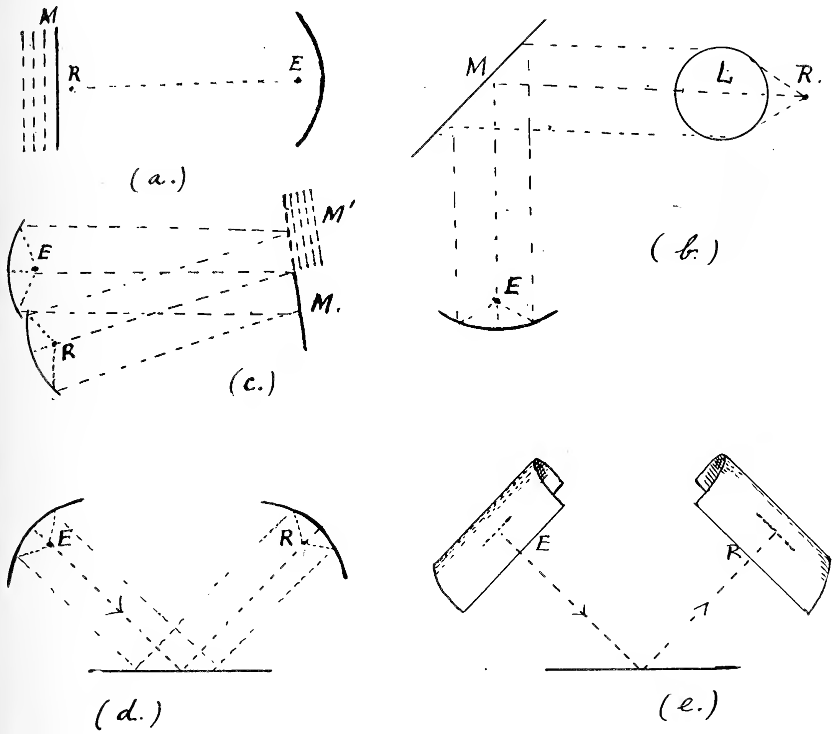
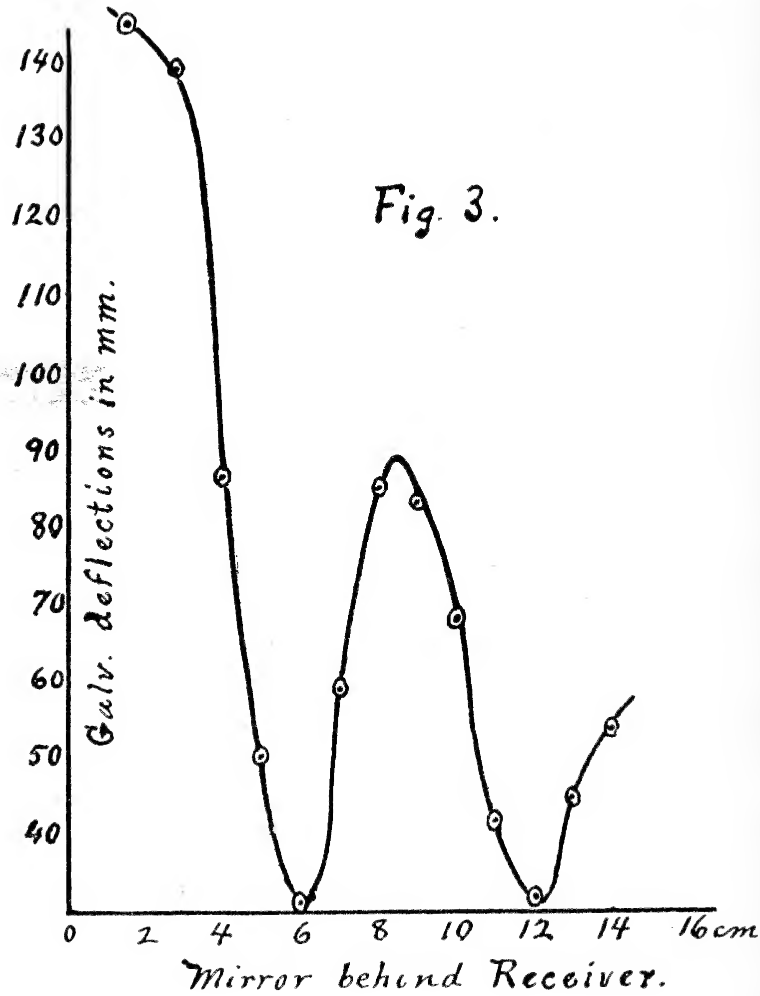


Fig. 2.

of the plane mirror behind the receiver are plotted as abcissae and the corresponding galvanometer deflections as ordinates. Two maxima and minima are well shown. With a mirror 1 foot square 3 maxima and 4 minima appear. (See *Phys. Rev.*, vol. 23, p. 244.)

The use of a thermojunction receiver (whose indications are proportional to the energy received) shows the rate of damping-out of the stationary waves, as well as the position of the nodes.

(2) *Rectilinear Propagation.* (Cf. Hertz, *Ausbreitung der electrischen Kraft*, p. 189). For this experiment the two revolving arms are brought into the same straight line, and exciter and



receiver placed about 1 meter apart. A metallic screen having about the dimensions of the aperture of the parabolic mirrors—say 35 cm. square—is placed upon the central table midway between them. The effect on the receiver is thus almost entirely

cut off, but only when the screen center is on the straight line connecting exciter and receiver. Ordinary sheet zinc is used for the screen.

(3) *Polarization.* In place of Hertz's huge polarization grating of parallel wires, we use a piece of cardboard, 35 cm. square, provided with parallel strips of tinfoil, each 2 mm. wide and 1 cm. apart.

(4) *Reflection.* Hertz's experiment showing the equality of the angles of incidence and reflection by a plane mirror, is readily repeated with the 35 cm. square sheet of zinc used in 2. The arrangement of apparatus is shown diagrammatically in fig. 2, *b*.

(5) *Refraction.* This is illustrated already in the action of the "bottle lens." Its efficiency in concentrating the radiation is easily shown by removing it in such an experiment as the last named. The effect on the receiver immediately falls to about one-fifth that before obtained. The experiment which Hertz performed with his gigantic 1300-lb. prism of street asphalt we have repeated, first with a hollow prism made of window glass having faces about 15 × 20 cm. and refracting angle 30°, filled with resin-oil. When water or alcohol is placed in the hollow prism, no measurable fraction passes through. Another larger prism of solid resin, with 30° angle and faces 25 cm. square, was later constructed and gave good results; showing a deviation of about 18°. This prism has become broken, and one of a less brittle material, hard paraffine, is being made to take its place.

(6) *Interference of Two Reflected Waves.* This famous experiment of Boltzmann is readily performed. The necessary arrangement of apparatus is shown in fig. 2, *c*. In this case two mirrors M and M^1 are used. At first both are in the same plane and act as one large mirror, reflecting the radiation received from E to the receiver at R. Then M^1 is shifted back a few centimeters at a time and readings taken for each position. A figure showing the interference curve for this case was shown in the paper in *Phys. Rev.*, vol. 20, p. 271, and is reproduced here as fig. 4.

(7) *Refractive Index by Interposed-plate Method.* By inserting a plate of dielectric material in the path of one of the interfering beams in the last experiment, the position of nodes and loops will be shifted because the radiation moves with diminished velocity in the dielectric medium. From the amount of this displacement the refractive index is readily calculated. We have used paraffine

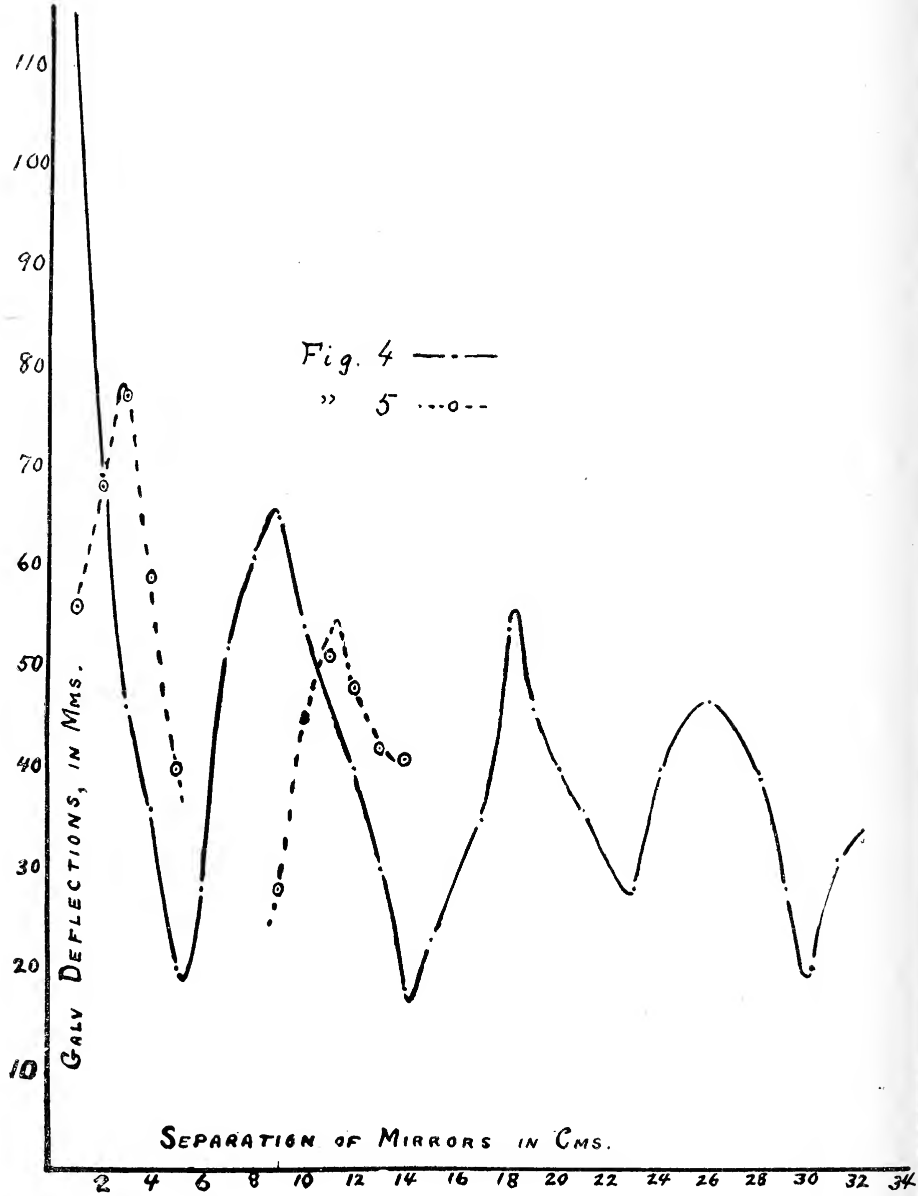


Fig. 4 —·—
" 5 ···o··
Galv Deflections, in Mms.
110
100
90
80
70
60
50
40
30
20
10
Separation of Mirrors in Cms.
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34

plates for this experiment. Fig. 5 shows the displacement of the first two maxima caused by the insertion of a plate of paraffine 5, 3 cm. thick. From this curve it appears that the first maximum is shifted 2.9 cm. and the second 2.7 or a mean of 2.8 cm.

Then the refractive index $\dfrac{5{\cdot}3 + 2.8}{5{\cdot}3} = 1{,}56$

Another similar experiment gave $\dfrac{1.49 +}{\text{mean } 1.52}$

(8) *Diffraction Phenomena.* A variety of diffraction effects can be shown with such an apparatus, such as the spreading of the

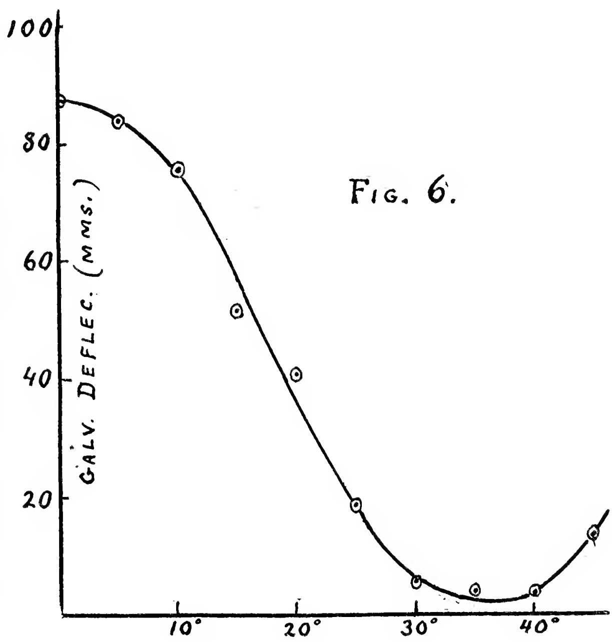


FIG. 6.

radiation after passing through a narrow aperture, the reflection of a larger amount of energy to a given receiver by a small plane mirror than by a considerably larger one diffraction bands by the use of a slit opening having a width suitably related to the wave-length employed, etc. Fig. 6 shows the first two "bright bands" with the intervening "dark band" obtained by the use of a slit, 17.6 cm. wide, interposed between exciter and receiver. In such experiments the receiver must be used without its usual

converging mirror or lens. It is admissible, however, to use a narrow metal strip placed one-quarter wave-length behind it as suggested by Righi in his book. We have used a narrow strip of sheet metal about 1.5 cm. wide. In fig. 6 abscissas give the angle in degrees through which the revolving receiver-arm was rotated from its central position and the ordinates the corresponding galvanometer deflection.

(9) *Amount of Reflected Energy Depended upon the Angle between Plane of Incidence and that of Vibration.* By revolving the cylindrical mirrors containing exciter and receiver, the proportion of radiation reflected by a surface of liquid is shown to be different with exciter and receiver in the relation shown in Fig. 2, *d* from that obtained in the position shown in Fig. 2, *e*. With water and an incident angle of 45° these ratios of reflected to incident energy are shown to be quite accurately such as are calculated from Fresnel's well-known formulas for reflection of polarized light, taking 8.95 as the refractive index of water for electric waves.

With alcohol the application of these formulæ to the results of a reflection experiment show a refractive index smaller than that found for longer waves. By this means anomalous dispersion for electric waves was discovered,[8] a discovery independently made by Drude a little later by an entirely different method.[9]

It is believed that the spectrometer form of mounting here described considerably facilitates the repetition of such classical experiments as are here described, strengthens the force of the optical analogies, and provides a suitable means for new research work.

Ohio State University.
April 28, 1909.

[7] H. Hertz, *Wied. Ann.*, 34, p. 610, '88.
[8] A. D. Cole, *Wied. Ann.*, 57, p. 310, '96.
[9] P. Drude, *Wied. Ann.*, 58, p. 1, 4, 18, '96.

THE DEVELOPMENT OF THE IDEA OF GLACIAL EROSION IN AMERICA.

FRANK CARNEY.

INTRODUCTION.

In this paper I give some brief citations, chronologically arranged, from such contributions of American students as represent a field study of glacial erosion, particularly in valleys; no attempt is made to trace the development of the cirque idea, or that of rock basins in mountainous areas. The literature contains numerous references, both incidental and extended, to the tendency of glacier ice to carve valleys; but until within the last decade these were disconnected observations representing, with few exceptions, local field experience if any at all, and in no individual case supplying data that could be correlated into convincing proof. Professor Davis summarized much of this literature up to 1882, giving many citations to show the development of the subject.[1]

What glacier ice, of either the Alpine or continental types, may have done in altering the surface it moved over has long been a matter of interest, sometimes disputatious interest; but the litera-

[1] W. M. Davis, "Glacial Erosion," *Proceedings of the Boston Society of Natural History*, vol. xxii, pp. 19–58, 1882. In the preceding volume of the *Proceedings*, pp. 336–45, Professor Davis gives a historical review of "The theory of the glacial origin of lakes." In vol. xxix, 1900, pp. 310–20, he reviews the "Previous writings on hanging valleys."

ture has generally grown less polemical with the increase of field knowledge. At the present time the belief in glacial erosion, locally even profound erosion, is almost universal.

It is many years since attention was first directed to the deepening of valleys as an evidence of glaciation. But for a long time no convincing proof was adduced. Perhaps the earliest observation approximating proof, and even this was not credited by many geologists, was King's description[2] of certain Cordilleran valleys which, passing downstream, change from a U-profile, ice-carved, to a V-profile, water-made. An appreciation of the distinction between the ice-modified and the water-made valley was of slow development. McGee[3] in 1883 briefly mentioned the relationship produced when ice makes a major valley wider, thus removing the terminal part of a tributary; but this intimation of the "hanging valley" condition apparently did not fix an impression in the minds of glacialists. In 1887 Russell gave a very accurate description of this relationship, but concluded that "the great inequality in the depth of the main glacial troughs and of their lateral branches is too great a work to be ascribed to the erosive power of ice."[4] The first description of an ice-produced discordance between a major and its tributary valley, given in sufficient detail and explicitness to merit acceptance, is that of Tarr in his "Lake Cayuga, a Rock Basin."[5]

1873 J. LECONTE.

Leconte says the fact that the Yosemite and other similar cañons in the Sierra Nevada "have been occupied by glaciers, makes it almost certain that they have been formed by this agency." "I must believe that all these deep perpendicular slots have been sawn out by the action of glaciers."[6]

[2] *Geological Exploration of the Fortieth Parallel*, vol. i, p. 478, 1873.

[3] W. J. McGee, *Proceedings of the American Association for the Advancement of Science*, p. 238, 1883.

[4] I. Russell, U. S. Geological Survey, *Eighth Annual Report*, part i, p. 352, 1889.

[5] *Bulletin of the Geological Society of America*, vol. v, pp. 339–56, 1894.

[6] Quoted from Davis, *Proceedings of the Boston Society of Natural History*, vol. xxii, p. 46, 1882. Leconte's statement appeared in *American Journal of Science*, vol. v, p. 339, 1873.

1878—CLARENCE KING.

One of King's conclusions from his study of glaciation in the Cordilleran section of the Fortieth Parallel Survey is the following: "There is not a particle of direct evidence, so far as I can see, to warrant the belief that these U-shaped cañons were given their peculiar form by other means than the actual ploughing erosion of glaciers; nor do the objections to this belief advanced by certain observers, based upon the moderate amount of detritus transported by the existing glacier-streams of the Alps, seem to be worthy of serious consideration, since the Alpine glaciers of the present day are at the best but the shrunken relics of the former system; and with vastly greater accumulation of snow in the ice period there is every reason to believe that the thickness, movement, and energy of the glacier must have been much greater, and that its power of abrasion would be correspondingly increased."[7]

1882—W. M. DAVIS.

In connection with Davis's arrangement of the evidence for and against glacial erosion, he makes the following comments: "It must be granted that the ice itself will suffer when pressed on its bed, and in spite of its long action will fail to produce much erosive change."[8]

"No sufficient reason has been given to show why the glaciers of the Italian slope of the Alps should be suddenly endowed near their ends with erosive power sufficient to cut out lakes 1000 to 2000 feet deep, while a little farther up stream their valleys were but slightly modified, as Ramsey himself claims."[9]

Professor Davis has since studied one of these valleys, and became convinced that ice had modified it; his discussion of ice-erosion in the Ticino valley, to be referred to later, is one of the great contributions to the subject.[10]

[7] *Loc. cit.*, p. 483.
[8] *Proceedings of the Boston Society of Natural History*, vol. xxii, p. 28.
[9] *Ibid.*, p. 53-54.
[10] *Appalachia*, "Glacial Erosion in the Valley of the Ticino," vol. ix, pp. 136–56, 1900.

1883—T. C. CHAMBERLIN.

The following statement is probably the first characterization of ice-work in the Finger lake region by a man of wide study and field experience in glacial geology:

"That these troughs were the preglacial channels of streams does not seem to me to admit of reasonable doubt; but that there was a *selection* and moulding by glacial corrasion seems equally clear; those channels that lay in the directions that would have been pursued had the ice moved on a uniform floor, being ground out wider, deeper, straighter, and smoother, while those in transverse directions were measurably filled and obscured."[11]

1892—D. F. LINCOLN.

After describing the surface features especially about Seneca and Cayuga lakes, he concludes: "The inference from these considerations is that the preglacial river which has been developed into Seneca lake must have occupied a level many hundreds of feet above the present bed of the lake."[12]

Following a descripiton of some valleys tributary to the Seneca valley, he says: "If these valleys, or any of them, had a preglacial existence and a rational connection with the lake valley, it would seem necessary to suppose that the bed of the latter then stood at an elevation 800 (?) feet higher than at present."[13]

1893—A. P. BRIGHAM.

Following a discussion of the Finger lakes, Brigham thus summarizes their origin: "To review briefly we suppose the basins to be a composite resultant of valley erosion, glacial scoop and drift barriers, with perhaps a slight element of orography."[14]

1894—R. S. TARR.

In a paper presented to the Geological Society of America in 1893, Tarr discusses the origin of the Finger lakes, particularly

[11] U. S. Geological Survey, *Third Annual Report*, p. 358.
[12] *American Journal of Science*, vol. xliv, p. 299.
[13] *Ibid.*, p. 300.
[14] *Bulletin of the American Geographical Society*, vol. xxv, p. 16.

the evidence of vigorous erosion in Cayuga valley. "In the Finger lake region the ice, moving from the northward, after entering the valley occupied by Lake Ontario, found its progress interfered with by the rising New York-Pennsylvanian plateau. Naturally the north-and-south valleys furnished lines of easiest escape, and naturally, also, the ice motion was here more powerful and the ice deeper. That the latter was true is proved by the fact that, even without the added depth due to ice erosion, these valleys were, at the beginning of the glacial invasion, at least 700 or 800 feet below the general upland level. This increase in thickness means, other things being favorable, an increase of erosive power."[15]

Tarr also gives detailed evidence showing the discordance of two valleys tributary to Cayuga valley; concerning one of these, Six-mile creek, he makes the following statement: "The north-and-south valley of Lake Cayuga is several hundred feet below it, and its depth has without question been caused by glacial erosion."[16]

1894—W. J. M'GEE.

After listing the characteristics of "glacial cañons," he says: "It follows that these features do not necessarily imply extensive glacial excavation or indicate that glaciers are superlatively energetic engines of erosion."[17]

1898—H. GANNETT.

Following a very complete description of glaciation in Lake Chelan valley, Gannett thus concludes: "There are therefore certain characteristics by which the gorge produced by glacial erosion may be distinguished from that produced by aqueous erosion. The glacial gorge has the shape of the capital letter U, while the water-worn gorge is a V-shaped notch. In a glacial gorge the spurs separating the tributaries have their ends blunted or planed off, while in a water-worn gorge they are sharp and angular. In a glacial gorge the tributaries enter the valley above its level, while in a water-worn gorge they commonly grade down

[15] *Bulletin of the Geological Society of America*, vol. v, p. 351.
[16] *Ibid.*, p. 350.
[17] *Journal of Geology*, vol. ii, p. 364.

to its level. A glacial gorge has an amphitheater at its head; a water-worn gorge has not."[18]

1899—A. P. BRIGHAM.

In an abstract of Brigham's paper "Glacial Erosion in the Aar valley" is this: "Below the lower Aar glacier, on the south side, a stream descends over the steep cliff face, carrying the waters of the upper Aar glacier. The lateral valley enters its principal some hundreds of feet above the floor of the latter, and thus is a typical case of the hanging valley. . . . . Similar hanging valleys enter from east and west at Innertkirchen."[19]

So far as I have been able to learn, this is the first published recognition by an American of "hanging valleys" in other lands.

1899—G. K. GILBERT.

In the discussion of Brigham's paper, Gilbert is reported thus: "He had been greatly impressed, years ago, by the magnitude of the glacial excavation indicated by such phenomena in the high Sierra, and last summer had found the coast of Alaska replete with similar evidence. After sailing for weeks through Alaskan fiords and observing scores of hanging valleys, he had come to regard their occurrence as diagnostic of the former extent of glaciation, and had used them with confidence as criteria for the discrimination of glaciated districts."[20]

1900—W. M. DAVIS

In discussing the "hanging valleys" of the Ticino he says: "The persistent association of this discordance with valleys that have been strongly glaciated points so conclusively to glacial erosion as its explanation that the doubts which I had long felt as to the ability of ice to erode deep valleys and basins—doubts which were not altogether dispelled by the arguments adduced by many glacialists regarding the U-shaped cross-section of ice-worn valleys, and by the form and distribution of lake basins—

[18] *National Geographic Magazine*, "Lake Chelan," vol. ix, p. 422.
[19] *Bulletin of the Geological Society of America*, vol. xi, p. 590.
[20] *Bulletin of the Geological Society of America*, vol. xi, p. 591, 1900.

were completely removed, and I came home with perhaps an over-ardent belief in the competence of glacial erosion, as is often the habit of the newly converted."[21]

Up to this time Davis had maintained a very conservative attitude when discussing glacial erosion; this conservatism appeared first in his "Basins of Glacial Erosion,"[22] and was explained in greater detail in later papers.[23]

1904—G. K. GILBERT.

Gilbert's studies in Alaska, on which was based his discussion of Brigham's paper at the Geological Society's meeting in 1899, were not published till this date. The following extracts make clear Gilbert's views on glacial erosion; his paper is one of the best contributions to the subject:

"The hanging valley is especially significant in two lines of physiographic interpretation. It is a conspicuous earmark of the former presence of glaciers; and it helps to a conception of the magnitude of Pleistocene glacial erosion."[24]

"The value of an earmark depends on the principle of exclusion: glaciation is the only physiographic process known to produce such forms."[25]

After discussing other processes that may result in mild cases of discordance between the grades of major and tributary streams, Gilbert says: "But despite all qualifications the hanging valley is the most important witness yet discovered to the magnitude of the work accomplished by the alpine glaciers of the Pleistocene."[26]

1905—H. L. FAIRCHILD.

That there is not complete unanimity in the interpretations based on field evidence is shown by the following which refers more particularly to the Finger lake valleys of New York:

[21] *Appalachia*, vol. ix, p. 139.

[22] *Proceedings of the Boston Society of Natural History*, vol. xxi, January, "On the Classification of Lake Basins," pp. 336–44, 1882.

[23] *Ibid.*, vol. xxii, May, 1882, "Glacial Erosion," pp. 19–58. U. S. Geological Survey, *18th Annual Report*, part ii, "Glacial Modification of Form and Drainage," pp. 179–81, 1898.

[24] *Harriman Alaska Expedition*, "Alaska," vol. iii, "Glaciers and Glaciation," p. 115.

[25] *Ibid.*, p. 116.

[26] *Ibid.*, p. 118.

"The most that can be reasonably claimed for ice-work is that it smoothed off the intervalley ridges and also the valley sides. The valleys are stream valleys, like valleys everywhere, and only slightly modified by ice action."

"Let us hope that assertions of the glacial origin or deepening of the Finger lake valleys (or any other valleys) will cease, and that former statements to that effect will be corrected."[27]

1906—R. S. TARR.

In discussing erosion in the Seneca valley, he says: "In this valley there is a general condition of remarkably perfect, broad, mature tributary valleys hanging several hundred feet above the lake level, at about the 900-foot contour. They are truncated by the straight, smooth, lower steepened slope of the main valley, so that they stand out prominently ,with open mouths, clearly discordant with the main valley, and about 1500 feet above the rock floor of the Seneca valley at Watkins."[28]

"When the hanging valleys of the Finger lake region were first recognized, and ice erosion proposed in explanation of them and of the main lake valleys,[29] there were few who accepted the conclusion advanced; but now the great majority of American physiographers accept the ice erosion explanation for this region, as well as for others."[30]

1906—W. M. DAVIS.

In connection with a discussion of "The present condition of the problem of glacial erosion," Davis states: "It has thus come to be believed by a number of observers that the glacial erosion of Piedmont lake basins must be extended to the over-deepening of the main mountain valleys far upstream from the lakes, and that the retrogressive glacial erosion of cirques carries with it the sapping and sharpening of the culminating ridges and peaks. The last named effect is truly not the direct work of ice, but it is so closely dependent upon glacial erosion that it should be included

[27] *Bulletin of the American Geological Society*, vol. xvi, "Ice Erosion Theory a Fallacy," p. 65.

[28] "Glacial Erosion in the Finger Lake Region," *Journal of Geology*, vol. xiv, p. 19.

[29] D. F. Lincoln, *American Journal of Science*, vol. xlix, pp. 290–93, 1892. R. S. Tarr, *Bulletin of the Geological Society of America*, vol. v, pp. 339–56, 1894.

[30] *The Popular Science Monthly*, vol. lxix, p. 391

in any discussion of the sculpture of mountains by glacial agencies; just as the wearing of slopes and ridges by the weather goes with the erosion of valley bottoms by rivers."[31]

1907—R. S. TARR.

After a very detailed description of conditions observed in Alaska, concerning hanging valleys he says: "It is also true that this phenomenon is practically confined to regions of former glaciation. Together with the U-shaped valley, truncated spurs, and steepened main valley slopes, the condition of hanging valleys is reported not only from a wide area in Alaska and British Columbia, but in such other regions of former glaciation as the Sierra Nevada, the Rocky Mountains, the Finger lake valleys of central New York, the coast of Norway, the Alps, the Himalayas, and New Zealand."[32]

1908.

Following a field study of glaciation in Scotland, Tarr's conclusions are illustrated thus:

"Loch Ness is quite like one of the Alaskan "canals." It is remarkably straight, has perfect truncated spurs, numerous hanging valleys and many waterfalls along its shores. The height of the hanging valleys above the lake bed varies greatly and seems to be proportioned to the size of the valley as one would expect."

"The measure of glacial erosion in many instances is hundreds of feet and in places perhaps as much as a thousand feet, thus being comparable to the erosive activity of the Alaskan glaciers and the continental glaciers in the Finger lake region of central New York."

CONCLUSION.

The above quotations characterize the development of the idea of glacial erosion in this counrty; the list might be increased for many of the years as well as for the intervening periods. My aim has been to call attention only to the writings of men who have studied the subject most widely in the field.

[31] *The Scottish Geographical Magazine*, vol. xxii, "The Sculpture of Mountains by Glaciers," p. 1.

[32] "Glacial Erosion in Alaska," *The Popular Science Monthly*, vol. lxx, p. 113.

It is observed (1) that the present day idea of the amount of glacial erosion does not differ much from estimates written thirty years ago; (2) that the method of, and the several lines of evidence of, ice-work were slowly understood and analyzed; and (3) that the most convincing evidence of deep valley erosion, the hanging valley, was described fifteen years ago, while the truncated spur characteristic was later recognized.

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February, 1909

PRELIMINARY NOTES ON CINCINNATIAN FOSSILS.

Aug. F. Foerste.

The attempt to identify all the fossils found in Cincinnatian areas with the forms already described by various American and European writers has the disadvantage that it fails to account for the numerous varieties which may be distinguished when forms from different faunal provinces and from different horizons are subjected to more exact study. For purposes of stratigraphical studies the recognition of these varieties often is of the greatest value. In the following notes attention is called to a number of these varieties. Some of these appear to be sufficiently distinct to warrant their designation as species.

The following table, indicating the classification of the Cincinnatian strata in Ohio, now in use, will be of service in determining the vertical distribution of these fossils:

Formations.	*Beds.*
Richmond	Elkhorn Whitewater Liberty Waynesville Arnheim
Maysville	Mount Auburn Corryville Bellevue Fairmount Mount Hope
Eden	McMicken Southgate Economy
Utica	Fulton
Cynthiana	Nicholas Point Pleasant

In this classification the term Nicholas is used to designate the more coarse grained limestone section at the top of the Cynthiana formation. Southwest of Pleasant Valley, in Nicholas county, Ky., this limestone section is typically developed and has a thickness of 35 feet. Northward, along the Ohio river, its thickness decreases. The term Point Pleasant should be restricted to the lower part of the exposures at Point Pleasant, as intended by Professor Orton. That part of the river quarry beds at Cincinnati which contains *Trinucleus concentricus* does not belong to the Point Pleasant part of the Cynthiana formation. Formerly, when these beds were studied by Professor Orton, the lower part of the section at Point Pleasant was well exposed, considerable quarrying was carried on, and the rock from these lower layers was sent in large quantities to Cincinnati. At present, scarcely a trace of these quarries can be found.

The Fulton layer is the *Triarthrus becki* horizon, about 5 feet thick. The Eden was described by Orton, but formerly included also the Mount Hope beds, now referred to the Maysville. The Maysville includes the strata assigned by Orton to the Hill quarry beds. The Richmond corresponds to the Lebanon beds of Orton.

Protarea richmondensis, nom. nov..

Corallum incrusting, forming a layer usually about 2 millimeters in thickness, but sometimes equalling 3 or 4 millimeters; with about 4 corallites in a width of 5 millimeters. There are twelve septæ, with distinctly denticulate inner margins, which reach scarcely to one-half of the distance from the walls to the center of the calyces. At the base of the calyces the denticles or granules are arranged rather irregularly. In the specimen selected as a type the calyces are rather deep and the septæ distinct. In numerous other specimens, represented by figs. 9 *A*, *B*, on plate 1, the incrustation is thinner, the calyces are more shallow, the septæ are not so clearly defined except near the margin of the calyx, and the granules scattered over the base of the calyx are larger and more conspicuous. In none of the specimens have any clearly defined vertical tubules been found between the walls of the corallites.

Protarea richmondensis is common in the Whitewater beds, at Dayton, Ohio, where the type specimens were obtained, and it is

abundant at this horizon in Ohio and Indiana. It occurs also in the Liberty bed.

The type specimen of *Protarea vetusta* consists apparently of a succession of lamellæ vaiying from 1 to 2 millimeters in thickness, and more or less free from each other in places. There are usually about 5 corallites in a width of 5 millimeters, although sometimes the corallites are wider. The vertical tubules between the corallites are fairly distinct under a lens. The calyces are rather deep, and the septæ scarcely reach halfway to the center. *Protarea vetusta* was described from the Trenton at Watertown, New York.

Leptæna richmondensis, nom. nov.

(*Plate IV, Figs. 10 A, B.*)

The typical *Leptæna rhomboidalis* is regarded as an Upper Silurian form, originally found as an erratic specimen. The concentric wrinkles are deep, fairly continuous, and the intervening concentric folds are stronger.

The typical forms of *Leptæna richmondensis* were found in the upper part of the Waynesville bed, at Madison, Ind. It is a common fossil in the upper or Blanchester division of the Waynesville in Ohio and Indiana, and in the upper part of the Whitewater, but it occurs also in the intervening horizons and is found fairly low in the Waynesville, though not at the base. Compared with *Strophomena rhomboidalis*, the concentric wrinkles are usually less numerous, less deep, especially toward the beak, and the radiating plications are broader, with narrower intervening grooves. The shell is relatively wider, and in most specimens the top of the pedicel valve is comparatively flat.

This species was figured by Meek as *Strophomena rhomboidalis* var. *tenuistriata*. *Leptæna tenuistriata*, Sowerby, is figured as having much more numerous radiating striations, and a different form.

Leptæna richmondensis—precursor, var. nov.

(*Plate IV, Fig. 11.*)

In the Arnheim bed at Arnheim, and at numerous other localities in Ohio, and still more commonly at the same horizon in Kentucky, a variety of *Leptæna richmondensis* is found which varies chiefly in having the top of the pedicel valve more convex. The shell

usually is less strongly geniculate anteriorly, and the concentric wrinkles are less conspicuous, often becoming nearly obsolete toward the beak.

Strophomena maysvillensis, sp. nov.

(*Plate IV, Figs. 13 A, B,*)

The type specimen of *Strophomena planoconvexa*, preserved in the American Museum of Natural History in New York City, is labeled as coming from Cincinnati, Ohio. Shells of this type are found at Cincinnati at the base of the Fairmount, at the line of contact with the Mount Hope bed. They are characterized by the moderate convexity of the brachial valve and the slight convexity of the pedicel valve. The shell is either subquadrate in outline, with the hinge line only slightly longer than the width across the middle of the shell, or the length of the hinge line is distinctly greater and the outline is more nearly semicircular. The muscular markings on the interior of the pedicel valve are not deep, and the shell is only slightly thickened on the interior of this valve.

In the case of *Strophomena maysvillensis*, the types of which were found in the lower Fairmount at Maysville, Ky., the shell usually is larger and relatively longer. The convexity of the brachial valve is greater. The outline frequently is subtriangular, the brachial valve being more or less nasute anteriorly. The shell is distinctly, though not very strongly thickened along the anterior and lateral parts of the interior of the pedicel valve. This thickening does not reach the actual margin of the shell and is crossed by short though distinct radiating vascular markings. *Strophomena maysvillensis* is very abundant in the lower part of the Fairmount in all parts of Kentucky and in Adams county, Ohio. In the more western parts of Ohio and in Indiana, *Strophomena planoconvexa* is more common at this horizon. At Williamstown, Paint Lick, and various other localities in western Kentucky, *Strophomena maysvillensis* is common at the base of the Fairmount and *Strophomena planoconvexa* is found in smaller numbers at a higher horizon in the same bed. *Strophomena maysvillensis* makes its first appearance in the lower part of the Mount Hope in Kentucky, occurring at this horizon in by far the greater part of the Ordovician areas, especially east and along

the crest of the Cincinnati geanticline. *Strophomena maysvillensis* is always identified as *Strophomena planoconvexa* to which it is undoubtedly closely related. It is a much more abundant form than the latter and is believed to be sufficiently distinct from the same to warrant a separate name.

Typical specimens of *Strophomena planoconvexa* are figured by Meek in volume I of the *Ohio Paleontology.*

Strophomena concordensis, sp. nov.

(*Plate IV, Fig. 6 A. B.*)

At the top of the Arnheim bed is a bluish clay, often indurated and weathering into so-called nodular masses. This layer is characterized at numerous localities in the more southwestern counties in the Ordovician areas of Ohio by the presence of great numbers of *Strophomena concordensis.* This species occurs also at the same horizon at Concord, in Kentucky. Three miles south of Maysville, at the deep cut on the railroad, it occurs in limestone at the top of the Arnheim.

This species belongs to the same group as *Strophomena nutans*, but it is larger than typical specimens of that species, and the interior of the pedicel valve is never thickened as strongly or abruptly as in that form. The thickening of the interior of the pedicel valve, in fact, usually is only moderate, and is crossed by vascular markings which are more conspicuously parallel or moderately radiating along the anterior border than in any other species. The brachial valve usually is more or less nasute anteriorly, and the view of the shell from the side of the pedicel valve is more or less triangular. The convexity of the brachial valve varies considerably, but usually is rather strong. The flattened part of the valve extends only from 6 to 9 millimeters from the beak, but the rapid downward part of the curvature often does not begin until 15 millimeters from the hinge line. The radiating striations are of the type found in *Strophomena planumbona.* The types are from Concord, Ky.

Dalmanella emacerata, Hall.

Thirteenth Report, New York State Cabinet of Natural History, 1860, p. 121.

No illustrations accompany the original description. In the

Fifteenth Report of the same series of publications, 1862, figs. 1, 2 and 3 on plate 2 are intended to illustrate this species. These figures differ considerably in outline; hence, fig. 1 is taken as the type. It evidently represents a brachial valve having a subquadrate outline, with a length equalling about three-fourths of the width. The type from which this figure was prepared is preserved in the American Museum of Natural History, in New York City. It evidently belongs to the coarsely striated forms usually listed under *Dalmanella emacerata*, and the coarseness of the striations is well represented by fig. 1, on plate 2 of the Fifteenth Report. In these forms about 8 to 10 striations occupy a width of 5 millimeters along the anterior margin of shells having a width of 20 millimeters.

Geological position. The type was received from Mr. Carley, and came from the Cincinnati Group, at Cincinnati, Ohio. The exact horizon from which the type came is unknown. Specimens having the same characteristics as the type were collected by Bassler and Albers in the *Triarthrus becki* horizon, or Fulton layer, at the base of the Eden formation. This Fulton layer is approximately equivalent to the Utica of New York. Specimens from this horizon are here regarded as typical. Specimens not distinguishable from the typical form have been received from various collectors from elevations of 60, 75 and 150 feet above the base of the Eden. This would extend its range into the Lower and Middle Eden. Further collecting from definite horizons is necessary. None of the forms figured by Meek as *Orthis emacerata* belong to this species.

Dalmanella emacerata—filosa.

(*Plate IV, Fig. 1*)

Some of the specimens referred to *Dalmanella emacerata* differ from the type in having considerably finer and more numerous striations. The specimen here figured, magnified 1.6 diameters, collected by Bassler from the *Triarthrus becki* horizon at Cincinnati, has 14 to 16 striations in a width of 5 millimeters. A similar specimen was found 150 feet above the base of the Eden. Until additional material has been collected it must remain doubtful whether these more finely striated forms should receive any separate designation.

Dalmanella bassleri, sp. nov.

A species of *Dalmanella* occurs near the base of the exposures at Carnestown, Ky., which appears to have been distinctly more robust and more convex than *Dalmanella emacerata* since the pedicel valves are always distinctly, though not strongly, convex, and the brachial valves, though nearly flat, are sufficiently convex toward the beak to make the shallow median depression fairly distinct. The radiating striations are numerous but appear coarser, and their fasciculate arrangement is more evident. *Dalmanella emacerata*, on the contrary, usually appears only in the form of very much flattened shells, even when forming the tops of layers of limestone.

The species from the lower beds at Carnestown often attain a large size. Some specimens 27 mm. wide, 22 mm. long, and about 4 mm. in depth are known. Striations corresponding to the radiating striations marking the exterior, are found on the interior of both valves, even where the muscular impressions should appear. The muscular area of the pedicel valve is distinctly limited posterolaterally by the ridges which are a continuation of the short plates supporting the short hinge teeth. Anteriorly these ridges soon become indistinct. An angulation in these ridges often indicates the point of demarcation between the anterior and posterior adductor impressions. There is no trace of muscular impressions in the brachial valve. A low median elevation divides the posterior part of the area where these impressions should occur. Posteriorly this elevation fills the lower part of the space between the short crural plates, and bears at its posterior end the short cardinal process, more or less trilobate posteriorly in some specimens.

At Carnestown, Ky., this species occurs associated with *Callopora multitabulata* and *Strophomena trentonensis*, between 8 and 15 feet above the Ohio river. At South Moscow, it is abundant immediately above the *Callopora multitabulata* horizon, about 11 feet above the Ohio river. It occurs at about the same horizon north of Butler, and at Parks Hill. East of Carnestown, it appears to occur in the lower part of the Cynthiana formation, and it is fairly common east of Florence, Indiana, opposite Warsaw. Farther south, it appears to occur in the Wilmore bed, belonging to the so-called Trenton of Kentucky. The Carnestown specimens appear to belong near the top of the Paris bed, forming the top of

this so-called Trenton. The chief interest of this species in the present connection is its presence apparently in the lower part of the Cynthiana division of the Cincinnatian in some of the localities along the Ohio river. Named in honor of Ray S. Bassler.

Dalmanella breviculus, nov. sp.

In the Middle Eden beds at Cincinnati, Ohio, flat finely striated forms of *Dalmanella* occur, with 14 striations in a width of 5 millimeters in specimens 20 millimeters wide. The ratio of the length to the width often is as low as two-thirds. The result is a semicircular outline, readily distinguished from the subquadrate outline of *Dalmanella emacerata-filosa*, which also has fine striations. The pedicel valve is moderately convex, especially anteriorly, the most convex part, one-third of the length of the shell from the beak, rising 3 millimeters above the margin of the valve. There is a shallow median depression in the brachial valve.

Geological position. The types came from the Middle Eden beds at Cincinnati, Ohio. It occurs at the same horizon at Vevay, Indiana. Somewhat similar forms have been secured by Cincinnati collectors about 60 feet above the base of the Eden. The types from the Middle Eden beds, at Cincinnati, will be illustrated later. In the meantime, fig. 2 on plate 2 of the *Fifteenth Report*, New York State Cabinet of Natural History, will serve as an excellent illustration of the species. It is not known, however, whether this specimen is still in existence, or from what horizon it came. Hence it is considered inadvisable to use the specimen there figured as a type.

Dalmanella fairmountensis, nov. sp.

(*Plate IV, Figs. 2 A, B, C.*)

Shell small, averaging 15 millimeters in width, but sometimes attaining a width of 18 millimeters. Shell usually wider posterior to the middle, the lateral edges more or less straightened, but converging anteriorly, suggesting a symmetrical trapezoidal rather than semicircular outline; however, shells with subquadrangular and with semicircular outlines also exist.

Pedicel valve with sides somewhat flattened and sloping away from a more or less distinct median axis of elevation; the latter

is most distinct posteriorly but frequently reaches the anterior margin. Lateral margins of the muscular area divergent as far as the anterior end of the exterior pair of diductor impressions, and then convergent with a sinuous curvature as far as the anterior margin of the second pair, between which there is a strongly reëntrant angle as far as the anterior edge of the adductor impressions. The adductor impressions are oblong and occupy about one-fifth of the width of the muscular area.

Brachial valve flattened toward the lateral margins, but slightly convex on each side of the distinct median depression; the latter is narrow near the beak, but widens anteriorly, and produces a distinct abrupt curvature in the outline of the shell when viewed from the anterior side. The strong and rather wide median elevation separating the adductor scars broadens posteriorly between the crural plates, and supports the cardinal process. The latter is divided by a median slit, and often is fairly conspicuous.

Geological position. Fairmount beds. The types are from the quarries in the southwestern part of Hamilton, Ohio, where it is abundant. It is much less common at New Trenton, and half a mile east of Dillsboro Station, in Indiana. It appears to have a very restricted geographical range.

Fig. 1*d* on plate 8 of volume i of the *Ohio Paleontology* appears to represent this species.

Dalmanella multisecta, Meek.

This species ranges throughout the Eden formation, into the Mount Hope and the base of the Fairmount beds. Two extremes have been figured by Meek. The type specimens, illustrated by figs. 3*a* to 3*d* on plate 8 of volume i of the *Ohio Paleontology*, have finer striæ, a more circular outline, and a more even convexity of the pedicel valve. The other extreme is illustrated by figs. 1*a* to 1*c* on the same plate, and is characterized by somewhat coarser striations, a more triangular outline, and a more angular convexity of the pedicel valve, best seen when viewed from the same side as the hinge area.

Dalmanella jugosa, James.

(*Plate IV, Figs. 16 A, 16 B.*)

Paleontologist, no. 4, p. 31, 1879.

This species was described by James from the upper beds of the Cincinnati Group, an expression which he used for the strata now included in the Richmond formation. His description includes two forms: one with a quite sharp mesial ridge on the pedicel valve, usually occurring low in the Waynesville bed in Clinton and neighboring counties in Ohio; and another with this mesial ridge but little conspicuous above the regular prominent convexity. Only the latter is abundant in the Richmond group over a wide area, and the latter is here regarded as the type. It is abundant in the Waynesville bed, especially below the Blanchester division of this bed, both in Ohio and Indiana. Very typical specimens occur at Oxford and Clarksville, Ohio.

Dalmanella meeki, Miller.

Cincinnati Quarterly Journal of Science, vol. 2, p. 20, 1875.

Miller, in describing *Orthis meeki*, not only copies verbatim the description of *Orthis emacerata* as identified by Meek in volume i of the *Ohio Paleontology*, but specifically states that figs. 2*a* to 2*g* on plate 8 of that volume are regarded as illustrating typical specimens of *Orthis meeki*. Therefore, the specimens figured by Meek must be considered as the types of *Orthis meeki*. Unfortunately, these types can not be found.

Meek states that the typical form of *Orthis emacerata*, as identified by him, occurred at an elevation of 250 feet above the Ohio river, at Cincinnati, and on other pages of the same volume he states that *Orthis multisecta* ranges up to 200 feet above low water mark, and that *Orthis bellula*, *Orthis ella*, *Orthis fissicosta*, and *Orthis plicatella* occur at 300 feet. There is nothing to indicate that the form he considered typical was at all common or had any considerable vertical range, although he had other specimens, differing very little, from higher horizons, both at Cincinnati, and in Butler county. This suggests that some large form of *Orthis multisecta* may have formed the basis of Meek's statement. This form should occur somewhere near the top of the Eden, and need not be common.

The specimen illustrated by figs. 2*a*, 2*b*, 2*e*, 2*f* and 2*g* may represent the large form of *Dalmanella multisecta*, if such a form exists; but, as far as may be determined from the figures, it appears to have been a good specimen of *Dalmanella jugosa*, from the Waynesville bed. While there may be large specimens of *Dalmanella multisecta*, in the Upper Eden, it does not seem likely that any of these would have dorsal valves as strongly convex as the one represented by figs. 2*e* and 2*f*.

Miller regarded Meek's statement concerning the horizon at which the specimens illustrated by figs. 2*a* to 2*g* were found as in error, and expressed the belief that these specimens came from Hamilton, in Butler county, Ohio. In fact, he states that the typical specimens 2*a* to 2*g* are quite common at the quarries in Hamilton, Butler county, associated with *Orthis ella*, *Orthis bellula*, *Orthis fissicosta*, *Orthis plicatella*, *Orthis sinuata*, *Glyptocrinus decadactylus*, and other species indicative of a range from 300 to 400 feet above low water mark, at Cincinnati; in other words, in the Fairmount beds. Since only the form here described as *Dalmanella fairmountensis* is common at this horizon at Hamilton, J. Mickleborough and A. G. Wetherby in their catalogue of *Lower Silurian Fossils of the Cincinnati* group, published in 1878, list *Orthis meeki* as a variety of *Orthis emacerata;* and James, in 1879, in the *Supplement* to his catalogue, regards it merely as a synonym of *Orthis emacerata*. That this is in error is shown by Miller, in his description of *Orthis multisecta*, in the same volume of the *Cincinnati Quarterly Journal of Science*, where he states of *Orthis multisecta*: "it is abundant at nearly all exposures from low water mark, at Cincinnati, to 250 feet above; after this, as we ascend in the strata the form which I have called *Orthis meeki* prevails in its stead. It would be impossible to determine where one form begins and the other ends, as they clearly intermingle, and leave the constantly recurring impression that they are not specifically distinct." Under his description of *Orthis meeki*, on the contrary, he states that this species can be readily distinguished from *Orthis emacerata*. That Miller was familiar with *Dalmanella emacerata* is shown by his statements that this species was found on Columbia avenue and on the Torrence road, 160 feet above low water mark, and was not known over 200 feet above low water mark, at Cincinnati. This is the Middle Eden horizon, at which *Dalmanella emacerata* is rather widely distributed.

Since *Dalmanella fairmountensis* might easily be regarded as a small form of *Dalmanella emacerata*, but scarcely as closely related to *Dalmanella multisecta*, this identification of the Fairmount species as *Dalmanella meeki* must be abandoned, notwithstanding the horizon assigned to it by Meek. From this it seems evident that Miller himself may have been in error in assigning his specimens of *Dalmanella meeki* to the Fairmount horizon. How he could possibly be in error regarding such a common form as *Dalmanella fairmountensis* at a locality so frequently visited by Cincinnati collectors as Hamilton, Ohio, it is difficult to understand. Possibly the fact that *Dalmanella jugosa* is common on the crests of all the hill ridges encircling Hamilton on the west, within three miles of the center of the city, and that the tops of the hills at the quarries within the boundaries of Hamilton are of Fairmount age, may have led to the confusion, especially in view of the fact that the intermediate region is poor collecting ground, and that the *Platystrophia lynx* horizon in the Mount Auburn bed is poorly developed there. It must be remembered that the subdivisions of the Cincinnatian, as established by Nickles, were not known at that time. In fact, the Catalogue published by Ulrich in 1880, the first serious attempt to work out the horizons of the various fossils, is full of errors natural to such a first attempt, when collectors often were not very communicative as to the source of their fossils.

Among the various reasons which have led to the identification of *Dalmanella meeki* as the Fairmount species is Miller's statement, following the republication of Meek's description, that *Orthis meeki* is smaller than *Orthis emacerata*. Now as a matter of fact, the great majority of specimens of *Orthis jugosa* occurring on the hill ridges west of Hamilton are distinctly smaller than most of the specimens of *Dalmanella emacerata* which I have collected from the Middle Eden, and if the remainder of Miller's comparison of *Orthis meeki* with *Orthis emacerata* be read, it must be conceded that this comparison is fully as applicable to *Orthis jugosa* as to *Orthis fairmountensis*, especially when it is stated that the striæ of *Orthis meeki* are not so fine.

On the other hand, how could Mickleborough, Wetherby, and James be mistaken as to the form described by Miller, when all lived in the same town and met frequently.

From a consideration of the preceding facts I have been led to

the conclusion that Miller probably had specimens of *Dalmanella jugosa* at hand when he described *Orthis meeki*, but this is rendered uncertain by his assigning the species to the Fairmount horizon, and by the fact that three collectors from the same town within 4 years of the first description of this species actually referred *Orthis meeki* to *Orthis emacerata*, which would be the natural affiliation of the Fairmount species. However, no matter what Miller intended to do, his republication of Meek's description of *Orthis emacerata* and his reference to figs. 2*a* to 2*g* as illustrations of typical specimens, would make Meek's types also the types of *Orthis meeki*. Meek's types can not be found. However, as long as no careful search has been made in the top of the Eden formation, or in the overlying strata, including the Fairmount, for large *Dalmanellas* which might have been used as a basis for Meek's description, and possibly also for his figures, the use of this term must remain uncertain. Large specimens of *Dalmanella* sent to me several years ago by Mr. John M. Nickles, and labeled as coming from the upper Eden, suggest that such forms may exist. Hence, for the present, the term *Dalmanella jugosa* seems preferable, until the identity of the specimens described by Meek has been established beyond all question.

Dalmanella (Bathycœlia) bellula, Meek.

Dalmanella bellula belongs to the group of *Dalmanellas*, typified by *Dalmanella subæquata*, Conrad, in which the brachial valve is strongly convex, and the median depression is absent or only faintly indicated. This group appears to have had a phylogenetic history distinct from the group typified by *Dalmanella testudinaria*. It ranges from the Stones river to the Devonian. For the species included in this group, the term *Bathycœlia* is proposed as a subgeneric term.

Plectorthis fissicosta, Hall.

(*Plate IV, Figs. 5 A, B.*)

The illustrations of the type specimen of *Orthis fissicosta*, preserved in the American Museum of Natural History, as presented in fig. 7, on plate 32 of volume i of the *Paleontology of New York*, is not sufficiently definite for present needs of paleontological study. For this reason, photoengraved illustrations, one of them

magnified, are herewith presented. These illustrations indicate that *Orthis fissicosta* is more nearly related to *Orthis triplicatella*, Meek, than at first supposed. In fact, *Orthis triplicatella* can scarcely be regarded as a distinct variety of *Orthis fissicosta*, Hall.

Plectorthis (Eridorthis) nicklesi, nov. sp.

(*Plate IV, Figs. 3 A, B, C, D.*)

Shell small, usually about 15 millimeters in width, and 11 millimeters in length, and with an estimated thickness varying between 3.5 and 4.5 millimeters.

The initial stages of the convex brachial valve begin with a median groove bordered by the first radiating plications. This median groove remains a distinctive feature of the mature shell and may be traced to a distance of 4 millimeters from the beak. Anterior to this, the various plications intercalated along the middle of the shell rise so as to form a median fold, often very distinct anteriorly, but sometimes only very slightly elevated. Each of the primary plications bordering immediately upon the initial median groove bifurcates very near the beak, and the inner one of these bifurcations usually forms part of the median fold anteriorly. Four or five of the plications forming the fold originate at or posterior to the middle of the shell. Sometimes several smaller plications are added anteriorly. Ten or eleven lateral plications originate on each side of the median fold posterior to the middle and to these plications others are added before reaching the margin. The result is a rather finely plicated shell. Distinct and rather distant concentric striations are easily recognized under a lens. Shell thin, with the radiating plications showing distinctly on the interior surface, and practically with no indication of the muscular scars. The median elevation which usually separates these scars, however, is plainly indicated. Posteriorly, it fills the lower part of the space between the crural plates, and supports the thin cardinal process, which thickens moderately anteriorly.

Pedicel valve beginning with a median plication which is not more prominent than the lateral primary plications. Beginning near the middle of the valve, the median part of the shell becomes depressed anteriorly, and forms a rather shallow sinus, including a smaller number of plications than those found on the median fold of the brachial valve. The pedicel valve usually is more

convex than the brachial, owing to the much greater height of the hinge area. Hinge teeth projecting but slightly beyond the cardinal line, supported by vertical plates uniting with the posterior part of the lateral border of the muscular area. Muscular area about 3.3 mm. in width and 4 mm. in length in a shell having a total length of 11 millimeters. The muscular area rests upon a callosity thickening anteriorly to a height of about three-fourths of a millimeter above the general surface of the interior of the valve. The muscular scar is divided lengthwise by two low striations into three divisions of which the middle one is slightly narrower, but projects a little farther anteriorly. In one case a narrow median striation is found along the central division of the muscular area. It is assumed that the lateral divisions correspond to the diductor muscular scars. How much of the middle division corresponds to the adductor scars is unknown.

Geological position. The types come from the Lower Eden, at Roger's Gap, Ky. They occur from this locality northward as far as Sadieville. Southeastward they may be traced as far as Hutchison in southwestern Bourbon county, and Riverside, in the southern part of Clark county. Along the Ohio river they have been traced from Cincinnati to Higginsport. They appear to be confined to the lower part of the Lower Eden.

The deep median groove in the initial stages of the brachial valve, and the well marked fold and sinus anteriorly on the two valves, produce a form quite distinct from the more typical forms referred to *Plectorthis*. For the group of shells typified by *Plectorthis nicklesi* and *Plectorthis rogersensis*, the subgeneric term *Eridorthis* is proposed.

Plectorthis (Eridorthis) rogersensis, nov. sp.

(*Plate IV, Figs. 4 A, B.*)

A second form, evidently so closely related to *Plectorthis nicklesi* as to be possibly only a variety, occurs at the same localities as that species, and at the same horizon. It appears to be more common at Roger's Gap than *Plectorthis nicklesi*, and differs chiefly in having distinctly fewer radiating plications, on the sinus, in the fold, and also laterally. The plications are broader, and the concentric striations are stronger and more distant.

Hebertella alveata, nom. nov.

(*Plate IV, Figs. 8 A, B.*)

The types are greatly prolonged at the hinge line, and have a distinct and broad median depression along the brachial valve, extending from the beak to the anterior margin of the shell. Another form, apparently merging into the former, but narrower, with the hinge line often slightly less than the width of the shell across the middle, and with the brachial valve often more convex from front to rear, occurs frequently in the Whitewater beds of Richmond, Indiana. The latter form may be called *Hebertella alveata-richmondensis*, and is mentioned only because at some localities it is common while the form with extended hinge line may be absent.

Shells having the form of *Hebertella alveolata* begin their existence in the Liberty bed, and are widely distributed in the Whitewater beds, in Ohio and Indiana. They were erroneously identified by Meek as *Orthis occidentalis*.

In *Hebertella occidentalis*, Hall, from the Maysville formation, as represented by the types preserved in the American Museum of Natural History in New York City, where they are labelled as coming from Cincinnati, Ohio, there is only a faint median depression near the beak of the brachial valve, disappearing anteriorly. This depression is scarcely discernible unless the shell is held in a favorable light. Judging from the types of *Orthis sinuata*, preserved in the same museum, the latter is only a more coarsely plicate form of *Orthis occidentalis*.

Austinella scovillei, Miller.

Journal, Cincinnati Society of Natural History, vol. 5, p. 40, 1882.

Dinorthis scovillei belongs to a group of species typified by *Orthis kankakensis*, McChesney and including also *Orthis whitfieldi*, N. H. Winchell. *Orthis kankakensis* and *Orthis whitfieldi* were listed by Hall, Clarke, and Schuchert under *Plectorthis*. *Orthis scovillei* was listed by them under *Hebertella*, but was placed by Nickles under *Dinorthis*.

The distinctly quadrate muscular scar of the ventral valve in these species suggests affinities with *Dinorthis*. This view is

favored also by the presence of vascular markings leaving the antero-lateral angles of the scars, and branching antero-laterally. These vascular markings are better shown by *Orthis scovillei*, but the most strongly developed part, nearest the muscular scars, is present also in the other species. This group differs from typical *Dinorthis*, however, in the form of the adductor scars, which are linear, extending to the anterior margin of the muscular area, as in typical *Hebertella*. In width, these adductor scars equal almost one-third of the width of the entire muscular area. While showing affinities to both *Dinorthis* and *Hebertella*, this group is sufficiently distinct from both to merit at least a subgeneric term, and the term *Austinella* is proposed, in honor of Dr. George M. Austin, to whom most of our knowledge of the vertical distribution of the Richmond brachiopoda of Ohio is due.

Platystrophia ponderosa, nom. nov.

(*Plate IV, Fig. 14.*)

The type specimen, here figured, came from the Bellevue bed at Madison, Indiana, where it is very abundant. In fact, this species is very abundant in the Bellevue bed in southern Indiana and Ohio, and in most parts of Kentucky. It is not infrequent in the upper part of the Fairmount bed at Maysville and elsewhere in Kentucky. At Maysville, and four miles west of Richmond, in Kentucky, a direct precursor of this species, almost of the same size, occurs in the upper part of the Middle Eden. It is much less common in the Corryville bed than in the Bellevue, but becomes common again in the Mount Auburn bed. It occurs commonly in the Arnheim bed in Kentucky, and in Bullitt county it is known even from the base of the Waynesville.

Platystrophia ponderosa is characterized by its large size, thick valves, and quadrangular outline; the brachial valve has a prominent, though rather rounded, median fold, usually occupied by four plications. The sinus on the pedicel valve is broad, not very deep, and is occupied usually by three plications. The lateral plications vary between 7 and 9. Sometimes 6 plications occupy the median fold. The shell is greatly thickened interiorly, especially around the deep muscular scar in the pedicel valve.

In form this shell appears to agree more nearly with *Platystrophia biforata*, Schlotheim, but Von Buch, who saw the type

specimen in the Royal Museum at Berlin, in 1838, stated that this specimen had 5 plications in the sinus. Moreover, in our specimens the sinus and fold appear respectively less deep and elevated, and the bounding surfaces less vertical than in specimens referred to *Platystrophia biforata* by Curt Gagel. Unfortunately very different forms have been referred to *Platystrophia biforata* at various times. The type of that species appears never to have been figured, and it seems to have been lost.

Platystrophia ponderosa—auburnensis, nom. nov.

(*Plate IV, Fig. 15.*)

The type of this variety was found in the Mount Auburn bed at Lebanon, Ohio. The variety is fairly common at the Mount Auburn horizon at Cincinnati, and at other localities in Ohio. It may be regarded as characteristic of that horizon, but does not exist there to the exclusion of *Platystrophia ponderosa*, of which it may be regarded as a more gerontic form. It is more globose, and has a distinctly shorter hinge line. As a rule the shell is narrower and the number of lateral plications is less, sometimes not exceeding 5 or 6, becoming obsolete toward the postero-lateral angles.

This variety appears to be closely related to *Platystrophia lynx*, Eichwald, as identified and figured by Curt Gagel. Eichwald describes the median fold of *Platystrophia lynx* as having 4 grooves so that there should be 5 plications. Von Buch states regarding the same species that it had 4 plications in the sinus and on the fold, and 9 plications on each side. The specimens figured by Curt Gagel as *Platystrophia lynx* are relatively longer, the fold and sinus are more abrupt, and the lateral plications are more numerous, and more distinct toward the postero-lateral angles than in the forms selected as types of *Platystrophia ponderosa-auburnensis*.

It is possible that the specimens figured by Meek as *Platystrophia lynx*, in volume i of the *Ohio Paleontology*, were obtained from the Mount Auburn horizon, but they do not have as short a hinge line as the variety here illustrated, they are less globose, and the lateral plications are more numerous and more distinct postero-laterally.

The type of *Platystrophia lynx* as described by Eichwald ap-

pears to have been lost, and no figuie was published of this type specimen.

Cyclocoelia sordida, Hall.

Paleontology of New York, vol. i, p. 148, 1847.

The type of *Orthis sordida*, preserved in the American Museum of Natural History, in New York City, is evidently a Cincinnatian species belonging to the group of *Orthis ella*. It has 21 primary plications, and one intercalated plication. In the description of *Orthis ella*, 15 to 20 simple plications are mentioned. The types of *Orthis elia* preserved in the American Museum of Natural History include 5 entire specimens. Of these three have 18 or 19 plications, a fourth specimen has 21 plications, and the fifth specimen, not typical according to the description, has 27 plications of which between 5 and 7 plications evidently are intercalated within 1 millimeter from the beak. *Orthis ella* does not form even a variety of *Orthis sordida*, but should be regarded as an exact synonym.

The pedicel valve has an open triangular delthyrium; the hinge teeth are supported by diverging vertical plates which extend only about two millimeters from the beak in case of shells having a length of 7 millimeters. Cross sections do not indicate the presence of any muscular area. No distinct hinge area is present. The brachial valve possesses two crural plates which appear to be rather broad and to terminate anteriorly in a point. A sharp median striation extends forward to almost 3 millimeters from the beak. No loops or spiralia were detected. One specimen appeared to show a short narrow cardinal process. All other specimens failed to give any definite information. The exact definition of this genus awaits further study. The term *Cyclocœlia* therefore can not be said to have established value, but it will serve at least to remove to a separate group a number of species, including *Orthis sectostriata*, Ulrich, which at present have no distinctive designation.

Rhynchotrema dentata—arnheimensis, var. nov.

(*Plate IV, Fig. 12.*)

The type of *Rhynchotrema dentata* was obtained from the Richmond group in some part of Ohio or Indiana. It appears to be an immature specimen of the Whitewater form, as found at Rich-

mond, Indiana, and elsewhere at the same horizon. It occurs also in the upper or Blanchester division of the Waynesville bed, and occasionally in the Liberty.

In the Arnheim bed, in many parts of Kentucky, at Goodlettsville, Newsom, and Clifton, in Tennessee, also at Arnheim, and a few other localities in Ohio, a variety of this species occurs which usually is larger, more triangular, less globose, especially along the posterior half of the shell, and usually with distinctly sharper, more angular plications. The degree of angularity attained by these specimens is not very well shown by the accompanying figure of a specimen from Arnheim, Ohio. The more typical specimens are abundant in the Arnheim bed south of the bridge across Salt river on the road from Mount Washington to Bardstown, in Kentucky.

Ceraurus miseneri, nov. sp.

(*Plate IV, Fig. 7 A, B.*)

The type specimen was found in the Whitewater bed at Richmond, Indiana. A fragment retaining the glabella and fixed cheeks was found at the same horizon at Dayton, Ohio.

The glabella widens from 5.6 at the rear to almost 9 millimeters anteriorly. There are three pairs of globular lateral lobes of which the posterior pair is distinctly separated from the median part of the glabella. The frontal lobe of the glabella, with its lateral extremities, has a semicircular outline. The occipital groove and its extension across the fixed cheeks is distinct. The eyes are prominent. The genal angles are blunt and rounded. The anterior outline of the head is moderately trilobate, owing to the reëntrant angles which are in line with the diverging sides of the glabella. Surface marked by coarse but rather distant granules.

Pleuræ with a large node posterior to the pleural groove, near the middle division of the thorax. Another large node is located at the point where the pleura is deflected downward. A third and smaller node is found between these two, but nearer the anterior margin.

PLATE IV.

Fig. 1. *Dalmanella emacerata-filosa.* Pedicel valve, enlarged 1.6 diameters.

Fig. 2. *Dalmanella fairmountensis.* All figures enlarged about 1.1 diameters. *A*, *B*, pedicel valves; *C*, brachial valve.

Fig. 3. *Plectorthis* (*Eridorthis*) *nicklesi.* *A*, *C*, pedicel valves; *B*, *D*, brachial valves.

Fig. 4. *Plectorthis* (*Eridorthis*) *rogersensis.* *A*, pedicel valve; *B*, brachial valve.

Fig. 5. *Plectorthis fissicosta*, Hall. Type. *A*, brachial valve; *B*, the same enlarged 1.6 diameters.

Fig. 6. *Strophomena concordensis.* *A*, interior of pedicel valve; *B*, brachial valve.

Fig. 7. *Ceraurus miseneri.* *A*, glabella and fixed cheeks; *B*, cephalon.

Fig. 8. *Hebertella alveata.* *A*, brachial valve; *B*, pedicel valve.

Fig. 8-*C*. *Hebertella alveata-richmondensis.* Brachial valve of a specimen which is not the type.

Fig. 9. *Protarea richmondensis.* *A*, on *Strophomena planumbona*; *B*, the same enlarged 1.6 diameters.

Fig. 10. *Leptæna richmondensis.* *A*, pedicel valve; *B*, brachial valve.

Fig. 11. *Leptæna richmondensis-precursor.* Pedicel valve.

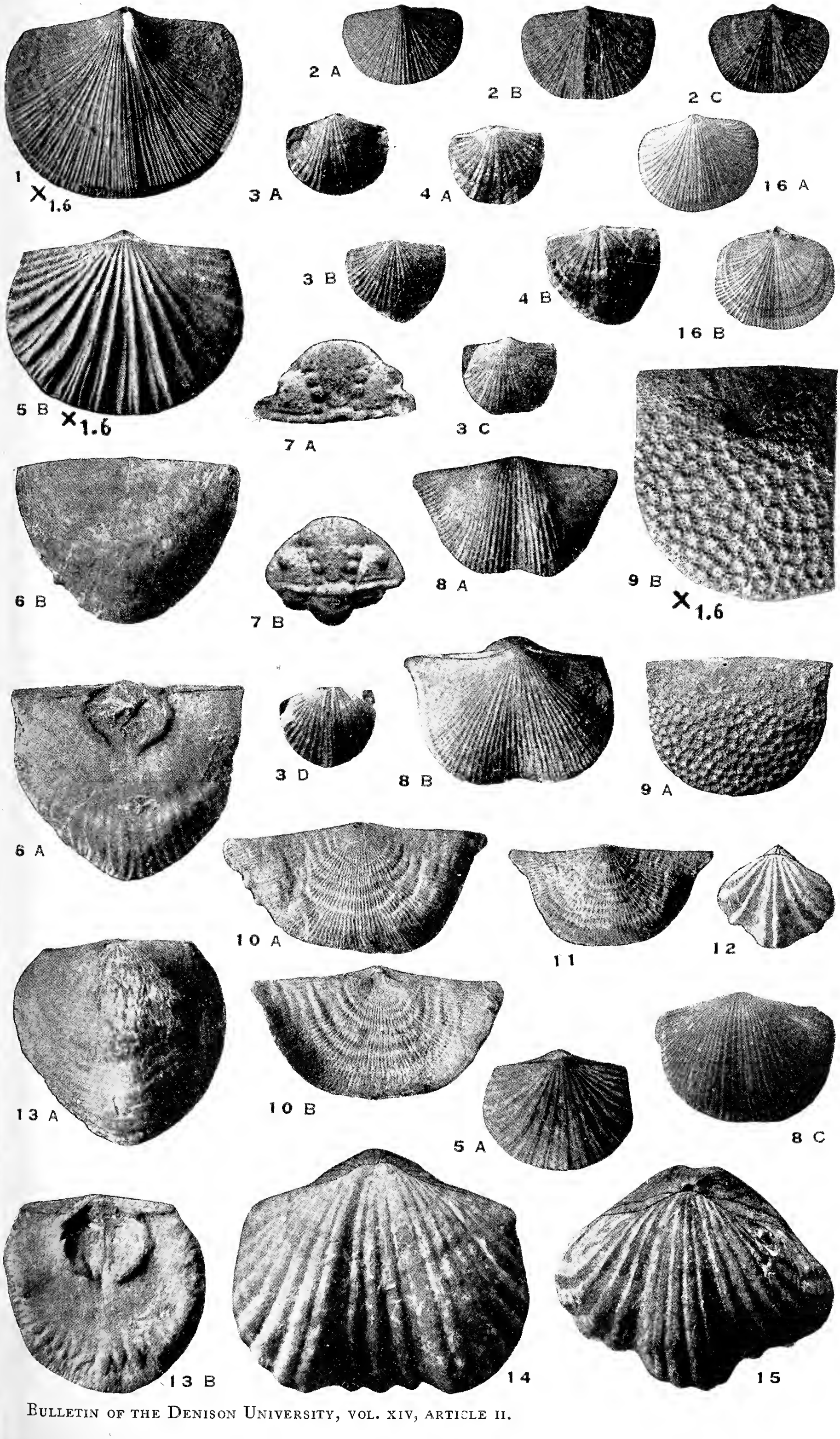
Fig. 12. *Rhynchotrema dentata-arnheimensis.* Brachial valve.

Fig. 13. *Strophomena maysvillensis.* *A*, Brachial valve; *B*, pedicel valve.

Fig. 14. *Platystrophia ponderosa.* Pedicel valve.

Fig. 15. *Platystrophia ponderosa-auburnensis.* Brachial view.

Fig. 16. *Dalmanella jugosa*, *A*, pedicel valve; *B*, brachial valve.


1 ×1.6
2 A
2 B
2 C
3 A
4 A
16 A
3 B
4 B
16 B
5 B ×1.6
7 A
3 C
6 B
7 B
8 A
9 B ×1.6
3 D
8 B
9 A
6 A
10 A
11
12
13 A
10 B
5 A
8 C
13 B
14
15

NOTES ON SPONDYLOMORUM QUATERNARIUM EHRENB.[1]

MALCOLM E. STICKNEY

All the members of the Volvox family command rather exceptional interest with botanists and zoölogists alike. Not only does their systematic position on the border line between animals and plants, and the fact that within the group various steps in the evolution of lower organisms including the evolution of sex may be traced, contribute to this interest, but their striking features of form and behavior and their sporadic occurrence has made them for the past two hundred years objects of much study. Spondylomorum, one of the simplest of the family, was first described by Ehrenberg[2] in 1848. Stein[3] later figured the adult colony with great clearness, and described certain phases of its life history and reproduction, presenting an account which stands practically without addition as representing our present knowledge of that form. Various observers have reported it as occurring in small ponds in certain parts of Germany, France, and upper Austria (De Toni[4]) in Europe, and in Connecticut (Conn)[5] in this country. Oltmanns[6] in presenting Stein's account of the vegetative habit and mode of reproduction of this form (the latter being given as essentially that of the vegetative reproduction of Gonium or Pandorina), deplores the insufficiency of our knowledge of this member of the Volvox group. It is with a view to making up this lack in certain few particulars that this very incomplete account is presented, based as it is upon studies extending over but a short time, and with a relatively small amount of material. It is expected that a more complete account may be forthcoming later, when more

[1] Contributions from the Botanical Laboratory of Denison University, no. x.

[2] Ehrenberg, C. G. *Monatsb. Berlin Akad.* p. 236. 1848.

[3] Stein, Fr. *Organismus der Infusionstiere,* 3:1. 1854.

[4] Detoni, J. B. *Sylloge Algarum,* 1: 534–559. 1889.

[5] Conn, H. A. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut. 1904.

[6] Oltmanns, F. *Morphologie und Biologie der Algen,* 1:134–163. 1904.

material may be at hand. The writer wishes to express his deep indebtedness to Prof. S. J. Holmes, of the Department of Zoölogy, University of Wisconsin, who very kindly furnished the material upon which this work was based, and whose suggestions in connection with the work were most helpful, and to his friend and pupil Miss Gertrude Lett, who made all the drawings here included.

For two years past Spondylomorum quaternarium Ehrenb. has been observed at Madison, Wisconsin, coming in in great numbers in aquaria containing old grass and dead leaves brought in from rain pools in early spring. The organism begins to make itself evident in such aquaria about ten days after the culture is started, rapidly increases in numbers for a few days, until portions of the aquaria are fairly green with masses of individuals, and then as gradually the culture dies out. All attempts to rear these organisms in the laboratory, other than in the above sporadic fashion, or to keep the cultures running for any length of time, have so far proved fruitless, although no more than tentative efforts to do this were made. The strong positive phototaxis which these organisms show makes their separation from the infusoria and bacteria of the culture water a very simple thing. By carefully transferring a pipette of material taken from the side of the aquarium illuminated by direct sunlight, to the shaded side of a small vessel of sterile water, and then almost immediately withdrawing a fresh pipetteful from the sunny side of the latter vessel, and repeating the process once or twice, a pure culture of Spondylomorum is readily obtained.

For the study of the grosser features of habit a method of preparation was employed which was suggested by Dr. Marquette of the University of Wisconsin in his work on the antherozoids of Marsilia. A drop of water containing a large number of individuals was placed on a clean slide and exposed to the fumes of osmic acid for a few minutes and then evaporated to dryness, thus fixing the organisms to the slide. The preparations were then stained with an aqueous solution of pyoktanin blue until the cilia were clearly brought out, when they were washed with water, again dried without heat, and mounted in benzole balsam. With rather dense organisms containing small vacuoles this method has proved very successful, as the contraction due to drying is slight, and certain details, including the cilia, are brought out with great clearness. Preparation of Spondylomorum made in this way show

very beautifully the mulberry-like habit of the colony, with its four alternating tiers of four cells each, as described by Stein; the cells loosely connected with one another by the interlocking of the long cilia (fig. 1). Other preparations were made from material fixed in the usual way with Flemming's weaker chrom-acetic-osmic mixture, embedded in paraffin, sectioned from three to six micra in thickness, and stained with Heidenhain's iron-alum hæmatoxylin or with Flemming's safranin-gentian violet-orange G. combination. Both staining methods yielded very good preparations, although those obtained by the triple combination gave, on the whole, clearer differentiation of the finer cell structures. No other methods of fixation or staining were tried. All the material for this study was fixed between the hours of sun-rise and eight o'clock on a bright morning, that of March 15, 1908.

With preparations of living material the colonies present a somewhat striking appearance as they move swiftly across the field of the microscope, rotating rapidly on their long axes. Evidently there is a strict coördination of movement among the different cilia of the various individuals of a colony, and a study of the behavior of these organisms would doubtless prove of great interest and value. In size the colonies are small, ranging according to their age from 15μ (very young) to 35μ (adult) in length, and from 12μ to 25μ in breadth. All the cells of a colony are alike in size, shape, and length of cilia. The individual cells are ovate in form, being somewhat more rounded in front and more pointed behind. The looseness of the union of the cells into the colony is shown by the numbers of individual cells which have become separated from the colony and are swimming about by themselves. The cells vary in size from 6.5 to 12μ long, and from 3.5 to 6.5μ wide. The cilia range from 22 to 35μ in length.

In each cell there is a single chromatophore of the Chlamydomonas type, deeply cup-shaped, the bottom of the cup being thick and filling the entire hinder end of the cell, while around the margin and extending forward it becomes very thin and shell-like. No pyrenoids are present. A red pigment spot is to be found on one side of the cell, usually not far from the nucleus. Two contractile vacuoles are present at the extreme anterior end of the cell, and these appear to contract alternately, as is the case with other members of the group. The nucleus is large and stands out very distinctly in well-stained preparations, surrounded by a region of

dense and strongly granular protoplasm. No nuclear reticulum could be made out in the resting nuclei, athough the nucleolus appears sharply defined as a deeply staining granule, apparently spherical and homogeneous in resting nuclei, and distinctly lobed in those which have recently divided (fig. 5).

The nucleus evidently divides with great rapidity in cells growing under favorable conditions, for while large numbers of dividing cells were found, and all stages in the reproduction of the colonies were freely represented, showing that nuclear division must have been taking place abundantly, only two nuclei in a state of actual division were found in the preparations studied. These division figures were both in late anaphase, with a clearly marked central spindle and chromosomes well drawn back toward the poles. The chromosomes appeared as very short rods, twice as long as wide, and while their number could not be made out with certainty, it was small, evidently in the neighborhood of six or eight. No centrosome could be distinguished, but the presence of the chromosomes in the polar regions would necessarily make it difficult to differentiate a separate centrosome body.

As has been noted, the cilia are four in number (fig. 2), and are nearly three times the length of the cell. They arise from a wart-like protuberance at the anterior end of the cell—the so-called "mouth-piece." In one preparation studied delicate fibers appeared extending back from the mouth-piece, between the vacuoles, to the vicinity of the nucleus. As these filaments were made out in but a single preparation it would be somewhat hazardous to attempt to identify them with similar structures of Dangeard[7] or Timberlake.[8]

According to Stein's account reproduction takes place in Spondylomorum essentially as in Pandorina and other members of the Volvox family, that is, by a division of the protoplast within the mother wall into sixteen daughter cells, which escape by the rupture of the enclosing membrane. The division, however, is not an internal one, but there is in every case a complete cleavage of the entire cell. Hence there is no "escape from the mother cell" on the part of the daughter colony, since the daughter colony was

[7] Dangeard, P. A. Etude sur la structure de la cellule et ses functions, Le Polytoma uvella. *Le Botaniste*, 8:1. 1901.

[8] Timberlake, H. G. Swarm-spores of Hydrodictyon. *Transactions of the Wisconsin Academy of Sciences*, 13: 486–515. 1901.

never enclosed in a parent wall. The first division in this cleavage process is as Stein suggested in the general plane of the long axis of the cell in most cases. The rule, however, is not absolute. The second division also usually approximates the plane of the long axis of the cell, and at right angles to the first. This division, however, is by no means as regular in its course as the first. The other two divisions apparently come in with no regularity whatever. It is of special interest to note that there is no rounding off on the part of the cell preparatory to reproduction. Cleavage takes place while the cilia are extended and the colony is motile. It is by no means unusual to see an old colony freely swimming about with each of its members in a four-celled, or even an eight-celled condition, and with no evidence of even the beginnings of a separation of the mother cells. Division appears to be simultaneous in the different individuals of a colony (fig. 7). As was indicated above, reproduction takes place in the early morning, and apparently goes on with great rapidity during periods of favorable conditions. It would be exceedingly interesting to follow the rate of growth and frequency of reproduction in these organisms, and determine the influence of external conditions, especially the periodicity of light and darkness and of heat and cold upon this phase of their activities. Nothing of this sort has been attempted in these studies. No evidence of sexuality has been observed.

Spondylomorum shows a number of features which would seem to place it in a position somewhat remote from the other colonial members of the Volvox group. The entire absence of a gelatinous covering for the colony, and the loose union of its individuals, and especially the mode of its reproduction by the entire cleavage of the cell, are all wholly uncharacteristic of the coenobic forms, and strongly recall some of the simpler unicellular members of the order. In fact it would not be hard to conceive of a Spondylomorum habit having its genesis in the entangling of the cilia of a unicellular form like Pyramimonas, a form evidently very near the orgin of the Volvocales, and the only member of the order resembling Spondylomorum in both lack of envelope and presence of total cleavage. Such a conception enables us to see in Spondylomorum an early step in the evolution of the coenobic habit in the Volvocales.

Granville, Ohio.
May 3, 1909.

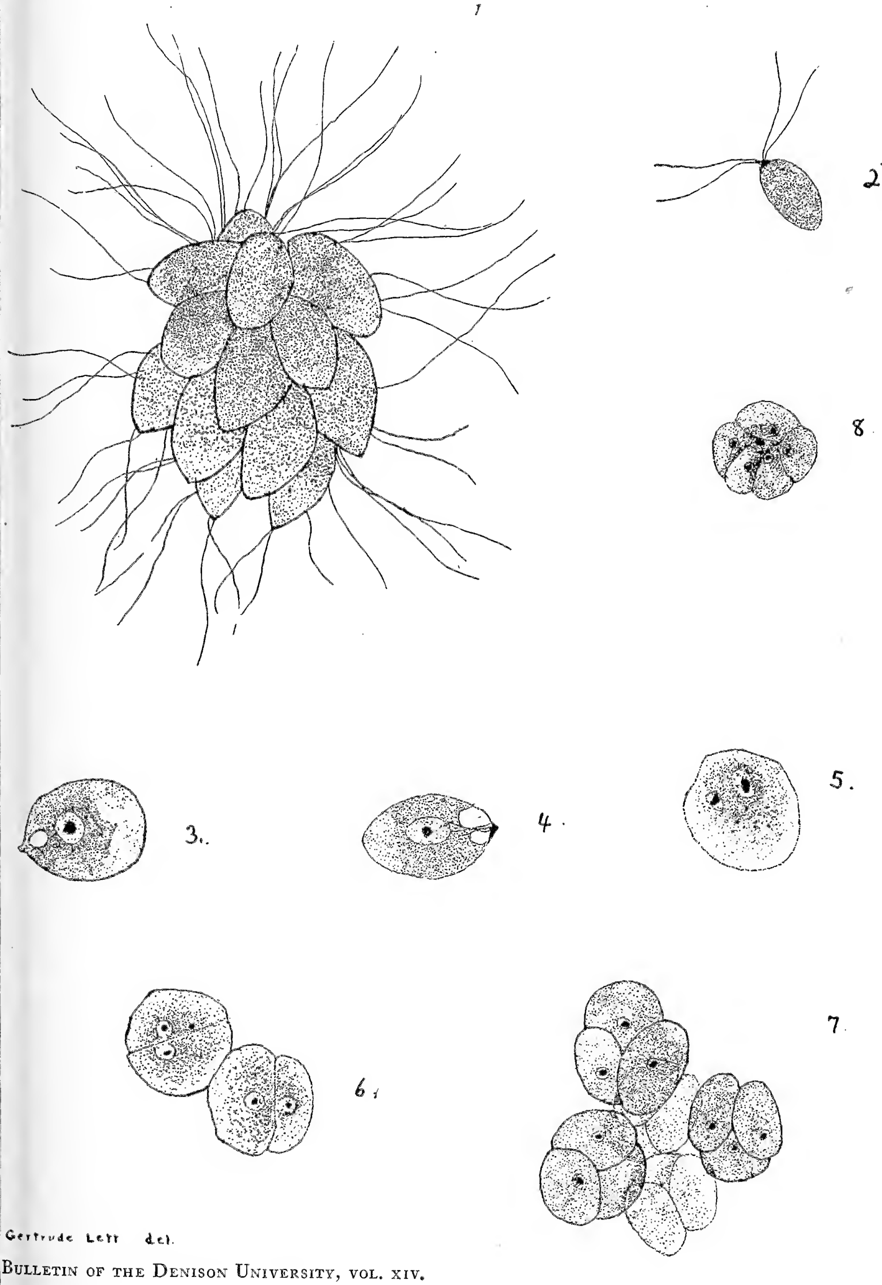
PLATE VI.

All figures were drawn with a camera lucida, using a Leitz $\frac{1}{12}$ oil immersion objective combined with ocular 4. The magnification here given is about 1500 diameters.

FIG. 1. Colony of Spondylomorum. General habit.
FIG. 2. Individual cell from colony.
FIG. 3 and Fig. 4. Longitudinal sections of adult individuals.
FIG. 5. Longitudinal section of cell immediately after nuclear division.
FIG. 6. Cell in transverse section, after first division.
FIG. 7. Group of cells after second division. Four-celled stage.
FIG. 8. Eight-celled stage, in nearly transverse section.

SPONDYLOMORUM QUATERNARIUM EHRENB. PLATE VI.

MALCOLM E. STICKNEY.



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THE REACTION TO TACTILE STIMULI AND THE DEVELOPMENT OF THE SWIMMING MOVEMENT IN EMBRYOS OF DIEMYCTYLUS TOROSUS, ESCHSCHOLTZ.[1]

G. E. Coghill.

Studies from the Neurological Laboratory of Denison University, No XXII.

In 1906 I began a series of experiments upon embryos of Rana and Amblystoma with a view to determining whether there is any regularity in the earliest neuro-muscular responses to tactile stimuli in the amphibian embryo. During the season of 1907 these experiments were continued upon embryos of Diemyctylus torosus, Eschscholtz (Triton torosus). Although the work of the first year gave interesting results and convinced me that the field of investigation was a fruitful one, it was less exhaustive and critical in its methods than the later work has been, and there is no occasion to give an account of it in this connection. It will, therefore, receive no further treatment here and all the data and discussions of this paper will relate exclusively to Diemyctylus torosus.

These experiments were originally planned for correlated anatomical and physiological studies. As an introduction to such work upon Amphibia they form the basis for the anatomical part, since they reveal distinct phases in the development of neuro-muscular response to the most primitive system of cutaneous receptors. But, apart from this significance to pure anatomy and physiology, they are, of themselves, an interesting contribution to the science of animal behavior, for they deal with a most important phase of behavior, namely, its very beginning in the embryo. If, for instance, there is any such thing as a "simple reflex," such as Sherrington suggests,[2] it must be found in the earliest reflexes of the embryo as observed in these experiments, and if it is possible to trace the

[1] Reprinted from *The Journal of Comparative Neurology and Psychology.* vol. xix, no. 1, April, 1909.

[2] Sherrington, Charles S. *The Integrative Action of the Nervous System*, p. 8.

development of a "simple reflex" into a form of acknowledged instinctive behavior, this link in the development of behavior would seem to appear in the development of the swimming movement as described in the following pages.

In view of this bearing of the experiments upon the subject of animal behavior certain results of the experimental part of my investigations are here made known before the anatomical phase of the work has been completed.

METHODS.

The embryos were removed from the egg membranes at various stages in development, ordinarily before they showed any sign of irritability to tactile stimuli. They were then placed in shallow Petri dishes, a single specimen in a dish, and tested from time to time for reactions. Usually an experiment continued until the animal began to swim.

The stimulus employed was a touch with the end of a rather fine human hair, mounted in such a way as to render the touch very gentle. The extreme sensitiveness of some very young embryos is remarkable. Even the touch of a fine piece of lint will at times evoke a vigorous response, as if it were a violent irritant.

Without critical consideration the tactile nature of this mode of stimulation might be held in doubt. The touch of a hair such as was used in these investigations might easily cause a considerable pressure, so that there might be a question whether the responses were to a strictly tactile stimulus or to a mechanical stimulus upon the muscles or central nervous system. Indeed, in the very early phase of development, when the irritability was for some reason unusually low, some of the reactions, I believe, may have been to direct pressure upon the muscles or central nervous system. But such instances, if they occurred at all, in these investigations, were, I believe, relatively rare. For instance, when the stimulus is applied to the under side of the head as the animal lies on its side, and the response is a movement of the head away from the side touched, it is inconceivable that this response is to a direct pressure upon the muscles effecting the movement, and it seems altogether improbable that such a stimulus could be brought to bear upon the central nervous system directly in such a manner as to give rise to a constant form of response. Or, in case the stimulus is applied

to the margin of the dorsal or ventral caudal fin and a movement of the head only results, as regularly occurs in certain phases of development, it is absolutely impossible for such a reaction to be given in response to pressure either upon the acting muscles or upon the central nervous system. As reactions of this sort occur here and there throughout nearly every one of my experiments, it seems to me certain that the stimulus employed was, with possible rare exceptions, purely tactile, and that, so far as the mode of stimulation is concerned, my conclusions are valid.

Ordinarily the stimulus was applied to the upper side of the specimen as it lay on its side on the bottom of the dish. Frequently however, it was applied to the under side of the specimen from beneath, in order to determine whether contact with the dish had any influence on the mode of reaction, but it was impossible to detect any factor of this kind in the responses. Some embryos, also, were suspended in an upright position and tested for the same purpose, and with the same result.

An individual record in detail was kept of each embryo from the time it was removed from the egg membranes till the end of the experiment. In the record of each trial, or application of the stimulus, the following factors were noted particularly: the region and side touched, the form of the response and the time of the trial. Tabulated schemes for rapid recording were tried in my first experiments of 1906, but it soon became apparent that such forms could not be adhered to, for they were necessarily based upon presumptions of some sort and were, therefore, a hindrance rather than a help to alert observation. These methods were wholly abandoned and have no part in the records from which this paper is written.

REACTION TO TACTILE STIMULI.

a. Response to Stimulation on the Head.

According to their reaction to a touch on the side of the head, in the region innervated by n. trigeminus or n. vagus, embryos of Diemyctylus torosus may be grouped according to three types, as follows:

Type I. Embryos which from the beginning and during a considerable period, respond regularly or almost regularly with a movement of the head directed away from the side touched.

Type II. Embryos which for a relatively short period at first respond irregularly with movements of the head toward or away from the side touched, and then enter upon a relatively long period of response like that of Type I.

Type III. Embryos which are at first asymmetrical in response, that is to say, they move their head in one direction only, regardless of the side touched, and then enter upon a short period of irregularity like the first period of Type II, and finally upon a relatively long period of response like that of Type I. Or individuals of this type may pass directly from the period of asymmetry to the regular form of Type I. The accompanying charts illustrate the behavior of typical specimens from each of these three types. The first column on the left in these charts records the serial number of the trials made, and the record of each trial is represented in the corresponding horizontal line to the right. The figures in the second column from the left record the time in hours and minutes that elapsed since the last preceding trial in each case. The diagrams in the third column from the left represent the form of reaction in the various trials. Where there is more than one diagram in a space these are to be read from left to right, and each represents a distinct phase in a series of movements. The arrow occasionally placed in these spaces indicates that a cephalo-caudal progression of the movement was distinctly observed. Where an "S" occurs the specimen swam, and the following diagram in the same space indicates the composition of the swimming movement. It should be noted that these diagrams of the movements are simply free-hand representations of the reaction according to written descriptions made at the time of trial. They cannot be considered as absolutely accurate in every detail, but they do represent truthfully the general order of the development of trunk movements in these animals.

The curves of the charts represent the side touched and the direction of the initial movement in the reaction relative to the side touched. The solid line records the direction of the movement of the head; divergence to the left from the vertical records a movement toward the side touched; divergence towards the right, away from the side touched; coincidence with the vertical, undetermined. The broken line records the side touched; divergence to the left signifies a touch on the left side of the head; divergence to the right, a touch on the right side; a blank, no record. Obviously,

where the two curves are parallel the movement recorded was to the left; where they diverge or converge the recorded movement was towards the right.

The apparent incompleteness in the serial numbers of the trials in the first column of some charts is due to the fact that in these experiments alternate or occasional trials were being made with reference to touch on the tail bud. The charts represent perfect series of trials with reference to touch on the side of the head.

The charts presented here are selected from a series which, with descriptions, has been deposited with the Wistar Institute of Anatomy and Biology, for the advantage of students who may be interested in a more exhaustive report of my experiments than this paper affords.

The accompanying table presents schematically some of the data upon which this classification into three types is based. It is the tabulation of the records of 36 specimens which have been selected solely upon the basis of completeness of the record and duration of the experiment. Owing to the difficulties in the manipulation of the work and unavoidable hindrances many experiments were not carried continuously through the entire period which is here under consideration, and, although contributing materially to the evidence on the problem as a whole, cannot, on that account, be included in a comparative study of this kind.

The several columns in this tabulation have significance as follows:

Column A. The number of the experiment, the data of which read to the right.

Column B. The time that elapsed between the last trial which gave no response and the first to which response occurred.

Column C. The time during which the embryo was asymmetrical in response.

Column D. The interval or time that elapsed between the last observed response that accorded with asymmetry and the first response that accorded with irregularity.

Column E. This is the second phase in the development of embryos of Type III, and the first phase of embryos of Type II. It is described above as the period of irregularity in response.

Column F. The interval or time that elapsed between the last observed reaction that accorded with irregularity and the first that accorded with the regular form of response as described above for Type I.

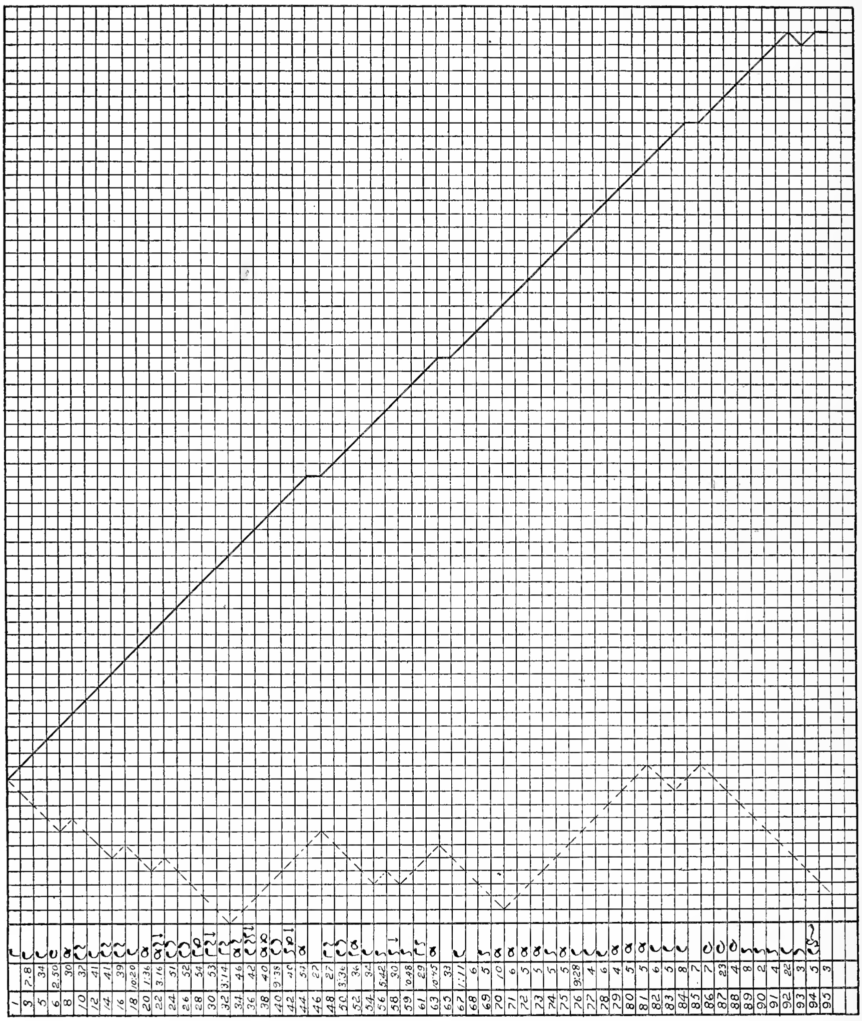

FIG. 1. Experiment 156, illustrating Type I. The embryo from which this record was made was the most regular of my series in response away from the side touched.

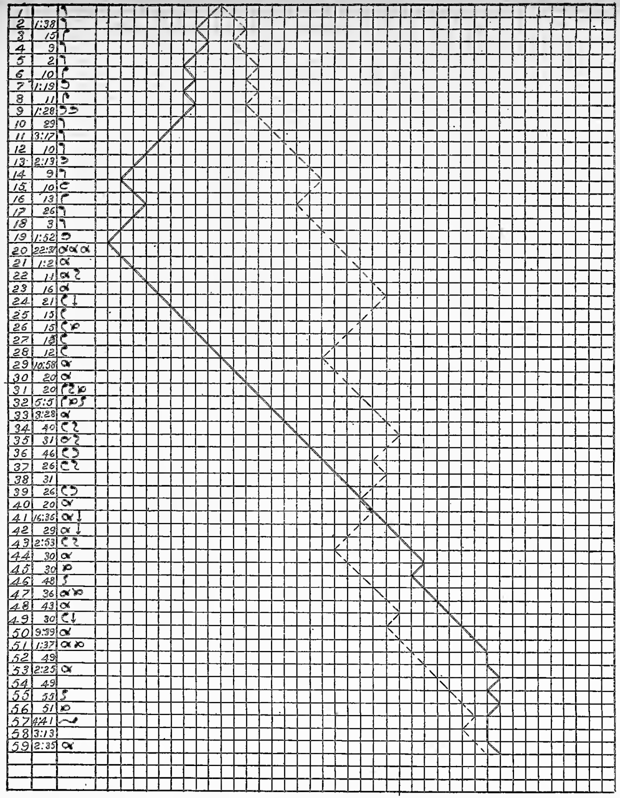

FIG 3. Experiment 136, illustrating Type III, in a case where the asymmetry passes over directly into regular response away from the side touched, but with a long interval.

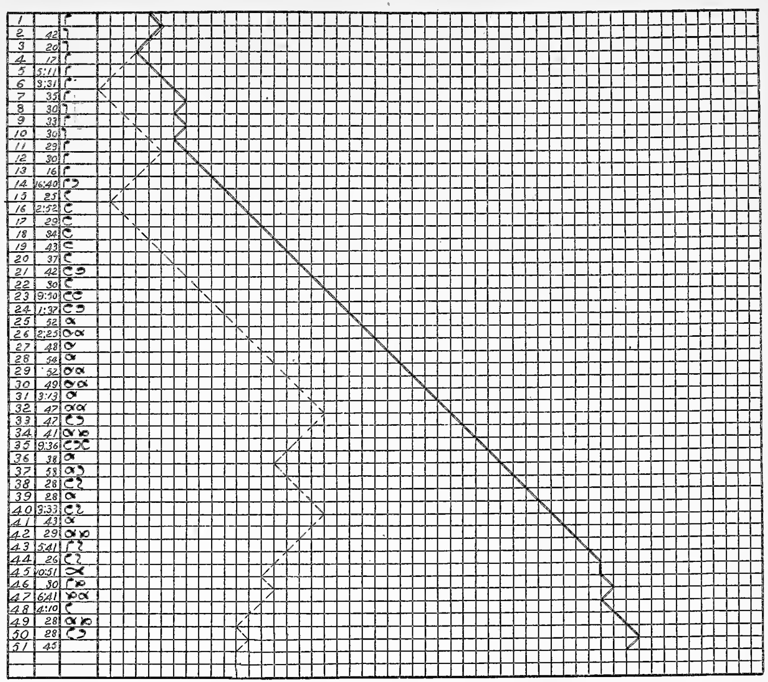

FIG 2. Experiment 151, illustrating Type II.

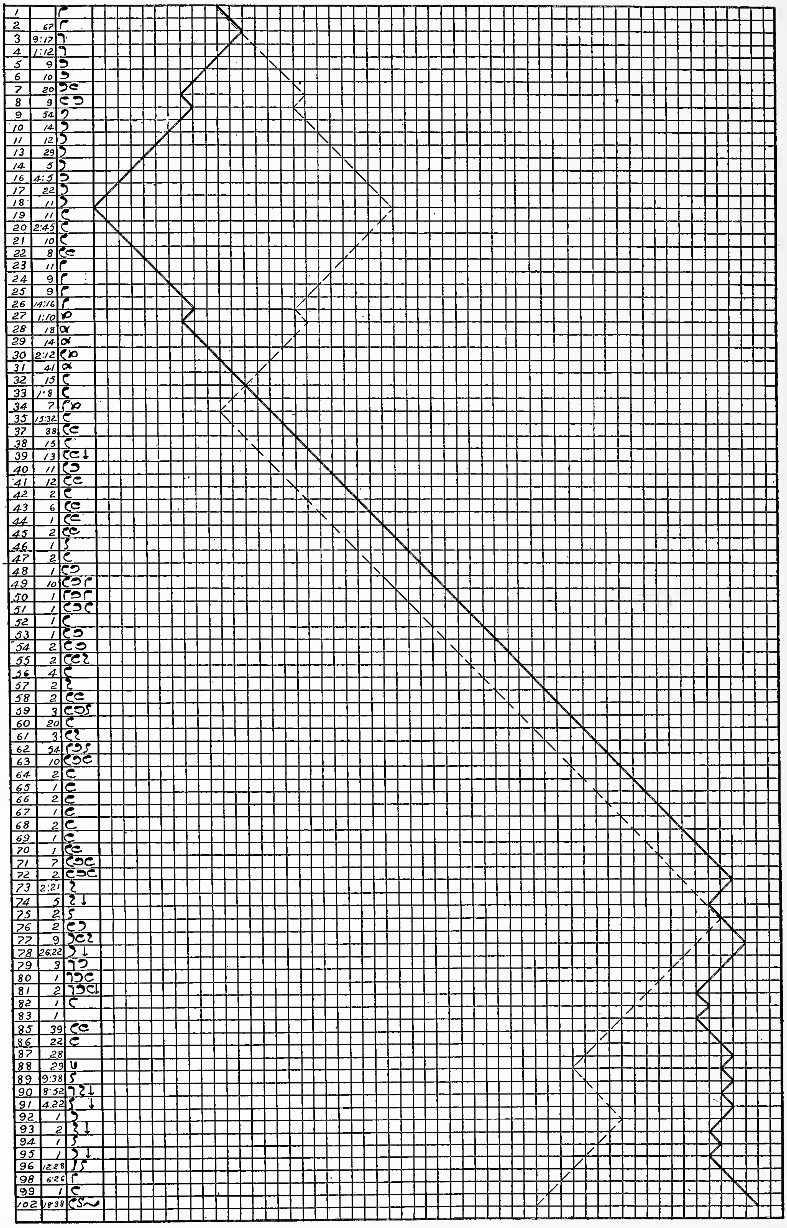

FIG. 4. Experiment 37, illustrating Type III, in a case where asymmetry in response passes abruptly into regularity, and the asymmetry is preceded by two movements at variance with it.

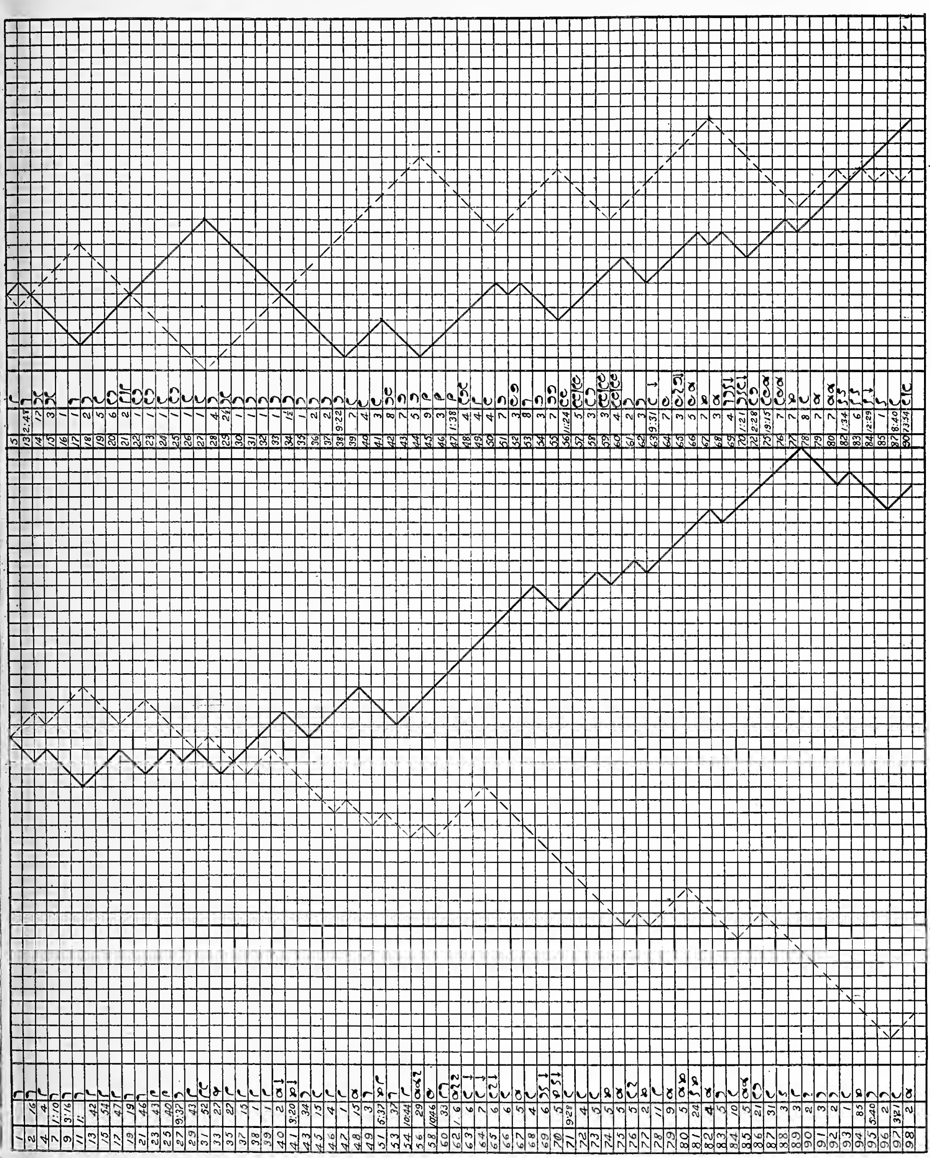

FIG. 5. (Upper figure.) Experiment 48, illustrating Type III, in a case where the period of irregularity is influenced, apparently, by the preceding asymmetry. It should be observed that the reactions were taken rapidly during the period of asymmetry and irregularity.

FIG. 6. (Lower figure.) Experiment 162. The embryo from which this record was made was, on the whole, the most irregular specimen of my series. Still, after the period af asymmetry there is a marked general tendency to move the head away from the side touched.

For further data see Table, p. 92.

A	B	C	D	E	F	G	H	I	
45	?	...	...	...	...	64:36	31	96.7	
32	?	...	...	...	...	52:07	53	94.3*	
146	24:00	...	...	...	...	72:00	40	100.0	
150	24:00	...	...	...	...	96:14	49	95.9	Type I.
145	24:00	...	...	...	...	73:34	40	95.	
144	20:22	...	...	...	...	67:52	35	97.1†	
156	13:30	...	...	...	...	96:43	57	100.	
Average..	21:10	...	...	...	...	74:43	305	97.4	
151	:20	...	...	12:19	:19	70:49	34	100.	
143	20:00	...	...	6:42	:19	48:09	25	96.	
147	5:45	...	...	2:27	11:00	71:09	35	91.4‡	
148	5:18	...	...	2:04	:14	64:41	24	100.	
149	?	...	...	1:35	:17	81:37	37	97.2‖	
374	3:53	...	...	1:52	9:29	49:02	37	100.	
142	20:00	...	...	6:29	:12	47:58	27	100.	
155	1:30	...	...	4:36	:27	59:04	23	100.	Type II.
158	24:00	...	...	11:49	:39	47:51	23	95.6‖	
161	?	...	...	:26	1:23	59:15	25	92.	
163	:41	...	...	5:10	:42	64:57	38	94.7**	
154	1:30	...	...	6:18	17:24	47:17	27	92.5	
140	1:30	...	...	8:34	:10	93:31	41	87.8	
141	14:00	...	...	33:21	:11	32:39	31	93.5	
36	?	...	...	26:47	14:01	37:34	19	94.7	
Average..	8:12	...	...	8:41	3:47	58:22	446	95.	
136	?	14:51	...	...	22:27	64:51	33	96.9††	
152	5:20	7:12	...	...	:58	58:04	22	100.	
159	2:54	8:26	...	...	10:22	69:13	24	91.6	
153	5:25	5:26	...	...	:43	66:10	32	96.8	
37	24:00	32:26	...	...	15:32	32:36	53	98.1	
39	?	:38	...	...	15:52	50:22	26	100.	
157	:14	7:31	...	...	2:39	72:53	30	96.6	Type III.
162	12:00	12:35	9:37	2:32	:27	45:08	46	78.2	
164	:40	23:48	5:38	11:59	:29	34:49	20	95.‡‡	
139	1:28	10:04	:22	2:26	22:45	68:12	39	97.4	
137	9:00	16:38	:07	6:26	22:44	62:25	33	93.3	
126	20:00	5:38	18:48	4:01	:09	98:48	60	98.3	
160	12:00	12:18	:43	:41	:41	58:36	37	89.1	
38	24:00	4:13	3:44	4:26	14:16	115:58	30	80.§§	
Average..	9:45	11:33	5:34	4:30	9:17	64:08	489	93.	

* The first 30 responses, distributed through 23 hours and 13 minutes, were all directed away from the side touched.

† During one period of 41 hours and 31 minutes there were 30 consecutive responses away from the side touched.

‡ During one period of 46 hours and 13 minutes there were 22 consecutive responses directed away from the side touched.

‖ During one period of 57 hours and 36 minutes there were 25 successive responses directed away from the side touched.

§ During one period of 36 hours and 50 minutes there were 18 successive reactions directed away from the side touched.

** During one period of 41 hours and 32 minutes there were 19 successive responses directed away from the side touched.

†† During one period of 47 hours and 6 minutes there were 25 successive reactions directed away from the side touched.

‡‡ During one period of 22 hours and 59 minutes there were 17 successive movements directed away from the side touched.

§§ There were in all 52 responses, distributed through a period of 137 hours and 33 minutes. Of these responses, 40 were directed away from the side touched, a percentage of 76.9.

Column G. The time during which the embryo is considered as moving its head regularly away from the side touched.

Column H. The number of responses given during the period represented by Column G.

Column I. The percentage of the responses indicated in Column H that were away from the side touched.

The time is recorded in each instance in hours and minutes, excepting in a few instances in Column B where the time was not determined. Averages are given in the several columns for each of the three types, excepting in Column H where the corresponding numbers represent totals.

With reference to the side touched in each trial my records are complete, but, inasmuch as the records in Column G clearly have no references to the side touched as determining factor, this element of the question is omitted from the table.

A comparison of the averages in Column B of the table might be interpreted to mean that the specimens of the second and third type came under observation relatively earlier in the period of development than did the specimens of the first type. But it should be noted that the figures in Column B represent the maximum possible time of irritability before the observation of it began. On the other hand, a comparison of the averages in Column G shows a clear distinction between Type I, on the one hand, and Types II and III, on the other. There is a difference of, say, 10 to 15 hours in the length of the period of regularity in moving the head away from the side touched. Furthermore, if the average of Column G for Type I be compared with the corresponding average for Type II plus the averages of Column E and F of this type, it will be seen that the embryos of Type I were longer in passing through the one period of regularity than were the embryos of Type II in passing through the periods of both regularity and irregularity, including the interval. It would seem, therefore, that a period of irregularity has not been passed over unobserved in Type I, and that the distinction between these two types is not based on the relative age of the individuals when they came under observations.

A similar comparison of the corresponding figures for Type III with those of Type I shows that the time represented by Columns E, F and G for Type III approximately equal that of Column G for Type I. But for the excessively long period of No. 38 in Column G, the comparison would result about the same as that

with Type II. But when the period of asymmetry and the following interval is taken into account it is clear that the specimens of Type III were a much longer time in passing through the periods represented by Columns C, D, E, F and G than were the specimens of Type I in passing through the period of Column G alone. This would seem to indicate that the condition of asymmetry is due to a precocious development of one side of the neuro-muscular system rather than to a retarded development of the other side. At any rate the sum of the averages in Columns C and D for Type III is greater than the average in Column B for Type II. It would seem altogether improbable, therefore, that a period of asymmetry like that of Type III has been passed over unobserved in Type II.

While I do not place any great dependence upon this comparison of the averages in the table, I believe they do tend to show that the difference between the different types of reaction as observed in these and numerous other embryos is not based upon relative age but upon the relative development, and probably the variable physiological condition, of the various constituent elements of the neuro-muscular system. When a period of asymmetry occurs, it appears before the period of irregularity or regularity, and never follows either of the latter, excepting in rare cases when one or two movements right at the beginning of the experiment are at variance with the asymmetry (figs. 3, 4, 5, 6). The asymmetry clearly influences the irregular reaction in some cases so that the movements toward the side touched appear to be determined by a partial persistence asymmetry (fig. 5). But this is not always the case. The period of regularity persists, ordinarily, till near the time of swimming. The actual length of the period varies greatly in different specimens, but a comparative study of numerous specimens convince me that the regularity in response is purest for a period of about 48 hours.

The structural basis for a regular asymmetry in response must be in the ascendency of the effector system of one side over that of the other, rather than in structural difference in the receptor systems of the two sides. Two facts particularly support this interpretation: (1) All spontaneous movements (somatic) that have been observed in embryos which conform to a given asymmetry are in accordance with the asymmetry in each case, toward the right in dextrally asymmetrical specimens and towards the left in sinistrally asymmetrical specimens. (2) In any given asymmetrical embryo

the asymmetry is the same with reference to stimulation on the tail bud as it is with reference to stimulation on the head, and specimens that are asymmetrical in one respect are so also in the other.

The structural basis for a regular movement of the head away from the side touched must obviously lie in the ascendency of the descending tracts which decussate in the cephalic part of the central nervous system over the uncrossed long tracts which descend into the cord. In comparing this condition with the response to stimulation on the tail bud, it should be remembered that the path from n. trigeminus or n. vagus to the opposite musculature of the cephalic part of the trunk is through the descending axones of these nerves within the central system, while the path from the caudal nerves to the same musculature is through the ascending axones of the afferent nerves. This factor will be best considered in connection with the account of reaction to touch on the tail bud.

The most difficult phase of the problem to deal with by way of anatomical inference or in the framing of a working hypothesis from the point of view of anatomy is the occasional response directed towards the side touched and the period of irregularity in response that precedes the period of regular movement away from the side touched. It is possible that in such cases the impulse passes directly to the centers of synapse with the effectors of the opposite side and, in case these centers are inactive, returns by a commissural path to the corresponding effectors of the same side; or it might be that the connection with the effectors of the same side is through collaterals of axones which themselves pass directly to the opposite side, and that, in case the opposite effectors are inactive the impulse may flow over into the collaterals and effect a connection with the effectors of the same side. Two observations may be cited in favor of the latter hypothesis: (1) There is a perceptibly lower degree of irritability during the periods of irregularity and asymmetry in response. My experiments are not exhaustive on this point, but they afford a considerable evidence to this effect, and none to the contrary. (2) The irritability of an embryo may vary perceptibly within a comparatively short period of time. This factor has not been definitely correlated with irregularity in response, but it may be the explanation of the occasional movement towards the side touched during the long period of predominant regularity. Also the very rare irregular movement occurring before a period of asymmetry, as observed above, may have its

basis in this variable irritability, at some point in the neuro-muscular system.

In some such manner as indicated above my experiments permit of a provisional hypothesis to explain the occurrence of the early periods of asymmetry and irregularity in response of some embryos and the occasional movement towards the side touched, and warrant the conclusion that, for a period of about 48 hours, or more, following the first movements in response to a tactile stimulus, the reponse of a symmetrically developed, normal embryo of Diemyctylus torosus is regularly away from the side touched when the stimulation is applied to the fields of the n. trigeminus and n. vagus.

b. Response to Stimulation of the Tail Bud.

There is no marked regularity in the responses to touches on the tail bud. There is a slight general tendency in some specimens towards movement of the head toward the side touched, but no definite significance can yet be attributed to this tendency. It is clear, however, that specimens that are asymmetrical with reference to stimulation on the head are similarly asymmetrical with reference to stimulation of the tail bud, and that ordinarily the asymmetry with reference to the two points of stimulation extends over approximately the same period.

One other fact concerning the reaction to stimulation on the tail bud is established beyond question by my experiments. The first response to such a stimulus in the very young embryo is a head movement, and as the embryo advances in age this movement still begins in the head region and progresses caudad. Ontogenetically, then, the most primitive conduction paths of the medulla spinalis are longitudinal and afferent, and the crossed paths are secondary, excepting possibly in the most cephalic part where the medulla spinalis may be involved in the crossed paths between the n. trigeminus or n. vagus and the opposite musculature of the trunk. The two halves of the medulla spinalis, therefore, seem to be physiologically distinct during this phase of development. This fact of development reveals from a new source the fundamental nature of the longitudinal divisions of the cerebro-spinal system, at least of the somatic components, as they have been conceived by Herrick,[3]

[3] The Cranial and First Spinal Nerves of Menidia, *Archives of Neurology and Psychology*, vol. ii, and *The Journrl of Comparative Neurology*, vol. ix; also numerous later papers, mostly in this Journal.

Johnston[4] and others on purely morphological and physiological grounds. It also suggests that in their direct connection with the cephalic part of the nervous system the special cutaneous systems of fishes and amphibians accord essentially with the primary plan of the general cutaneous system.

It would be a difficult thing ordinarily to demonstrate that the receptive fields and afferent conductors become functional in an embryo before the effectors do, for through the effectors alone is the functioning of the receptor and conductor demonstrable. But if the skin of a given somite in the tail bud of an amphibian embryo of suitable age be touched there will be no perceptible response in the effectors of that segment, while response will occur in the older somites farther cephalad. Into this given caudal somite, then, impulses are pouring from the external world through the receptors and conductors before the effectors of that segment are capable of making any perceptible response whatever. If this is true of the more caudal somites, it may be assumed to be true of the head segments also, and the embryo may be regarded as existing under a storm of impulses of the receptive system for a considerable period before it has the ability to give expression through its effectors. How widely this order of development of the receptor and effector may be applicable, as a law, and what its significance may be are questions of interest. It is possible that the summation of subliminal stimuli in neuro-muscular reflexes rests upon this as a fundamental principle of functional development. It is possible, also, that Kappers[5] might correlate this precocity of the afferent system with his theory of neurobiotaxis, in which he assumes that the afferent conductors have influence over the effector centers to cause them to migrate, phylogenetically at least, in the direction of the maximal amount of stimulation.

[4] The Brain of Acipenser. *Zoöl. Jahrb.*, 1901; *The Nervous System of Vertebrates*, Philadelphia, 1906; and other papers in this Journal.

[5] Phylogenetische Verlagerungen der motorishen Oblongatakerne, ihre Ursache und Bedeutung. *Neurol. Centralbl.*, no. 18, 1907.

Weitere Mitteilungen bezüglich der phylogenetischen Verlagerung der motorischen Hirnnervenkerne. Der Bau des autonomen Systemes. *Folia Neuro-Biologica*, B., Nr. 2, January, 1908.

Weitere Mittheilungen über Neurobiotaxis. *Folia Neuro-Biologica*, B. 1, Nr. 4, 1908.

The Structure of the Autonomic Nervous System Compared with its Functional Activity. *Journal of Physiology*, vol. xxxvii, no. 2, 1908.

THE SWIMMING MOVEMENT.

The movements of Diemyctylus embryos are of two main types: (1) the flexure, which is a bending of the body in one direction only; (2) the "S" movement or reaction, which is a bending of the more cephalic and the more caudal parts of the body in opposite directions, giving the form of the letter S.

The flexure may occur in several varieties. It may be a "head flexure," which effects a movement of the head only; a "pectoral flexure," which affects slightly more of the trunk than the head flexure does; a "mid-trunk flexure," which is effected by the muscles of the middle portion of the trunk only; a "general flexure," which involves the bending of the whole trunk. In the mid-trunk or pectoral flexure the parts cephalad and caudad of the flexed part may assume positions parallel to each other, in the form of the letter U. This may be designated as the "U" reaction. The general flexure may be extended till the body assumes more or less a coiled condition. This movement may be termed the "coiled reaction."

The various forms of the flexure are not to be considered as essentially distinct, for, with possibly the exception of the U reaction, they develop gradually one into the other in the order mentioned. Nevertheless, the distinctions are useful for descriptive purposes.

The first member of this series to appear in the course of development of the embryo is the head flexure; the next is the pectoral flexure, and, as the embryo advances in age, the flexure extends farther caudad until it involves the entire trunk in a general flexure, and, finally, in a coiled reaction. In ontogeny, then, the flexure develops cephalo-caudad. This is true for responses to stimulation on the tail bud as well as for responses to stimulation on the head.

In the development of any particular flexure, pectoral, general or coiled, the same progression cephalo-caudad is observed. If the n. trigeminus or n. vagus is stimulated by a touch, the normal reaction is a head flexure, and, if the embryo is sufficiently advanced in age, this flexure progresses caudad until the whole trunk is involved. In like manner, if the touch is upon the tail bud, the response begins in the head region and progresses caudad. The physiological development of a flexure, then, is correlated with its ontogenetic development.

Now, so far as my observations go, the S reaction never appears until the embryo is capable of executing an extended general flexure, and rarely until it has actually executed a coiled reaction. Furthermore the S reaction is ordinarily first performed by a reversal of the head from an extended general flexure or a coiled reaction before the original flexure is completed in the caudal part of the trunk. This reversed movement of the head, in early stage of the embryo, may simply progress caudal till it reverses completely the original flexure; but when the movement attains its typical form it is a relatively short, quick movement, and, when performed in series, it becomes the normal swimming movement.

The occurrence of the S reaction in series has its origin, evidently, in a mode of response which appears very early in the course of development. It may be designated as the "secondary reaction." This secondary reaction is a movement that is made during the phase of relaxation from a direct response to an external stimulus. It is caused, probably, by a rhythmic process in the motor cells, or, possibly, by stimuli from the proprio-ceptive field. It may be of greater or less extent than the original flexure. It may, for instance, advance a general flexure into a coiled reaction. It is a conspicuous feature in the behavior up to the time when the S reaction appears.

Now, it is obvious that when the head is once reversed from a flexure into an S reaction, the secondary reaction would explain the second reversal, which is simply repetition of the initial movement. The successive reversals of the head may, then, be initiated as secondary reactions and the progression of the successive flexures caudad, in the form of S reactions, propels the animal forward.

Locomotion, therefore, in the amphibian embryo is dependent upon the progression of the flexure cephalo-caudad, and the cephalo-caudal progression of the individual movement is further correlated with a similar progression in the ontogenetic development of the reaction. Furthermore, it is clear that this order of development of function is correlated with the order of structural development of the central nervous system, as illustrated, for instance, in the order of closure of the neural tube. These correlations naturally suggest, further, that the necessity of locomotion may have been an important phylogenetic factor in determining the order of development of the parts of the nervous system in vertebrates.

Emphasis, properly, has been placed, by authorities generally,

upon the principle of cephalization as correlated with the organs of special sense; but these early movements of the embryo show, that so far as functional development is concerned, the most primitive centralization of the nervous system, ontogenetically, is in direct response to the demands of the motor system in its relation to locomotion, while the sensory system involved is not the special sensory but the most primitive, diffuse, exteroceptive field. It remains to locate exactly this primitive center of the cerebro-spinal system by correlated anatomical and experimental studies; but from the experiments alone, this center would seem to be in close relation to the cephalic musculature of the trunk. This is inferred particularly from the fact that a flexure in response to a touch on the tail bud begins in the head region and progresses caudad and is the same in form (without reference to the initial direction of the movement) as the flexure that follows stimulation of the head. All movements, then, regardless of the point of stimulation, must emanate from the same center. Into the center all impulses would seem to flow in order to be directed in such a way upon the musculature of the trunk as to give rise to locomotion. Clearly the development of an eye or ear as such in its earliest functional condition has no part in determining this region of centralization. The controlling factor in this centralization is the motor system: a cephalization in response to the prepotency of the requirements of effectors and not in response to the demands of the cephalic receptive fields.

Phylogenetically, then, the most primitive cephalization of the nervous system may have occurred, also, in response to the demands for locomotion and have given rise to a center of control in the region corresponding to the lower portion of the myelencephalon or the upper portion of the medulla spinalis. Quite in harmony with this suggestion is the convincing evidence that Johnston[6] presents for the migration caudad of the afferent roots of the cranial nerves. Such a change in their course would lead them more directly into this primitive locomotor center. Upon this hypothesis, also, the economy of the arrangement of the special cutaneous nerves of fishes and amphibians is obvious. It is not to be supposed that the cephalization of the locomotor effectors is, in any respect, a direct cause of the cephalo-caudal migration of the

[6] *The Nervous System of Vertebrates*, chapter iii.

special cutaneous receptors and conductors, but such a cephalization would certainly favor the development of such systems, for, as already suggested, their peripheral conductors hold essentially the same relation to the cephalic part of the central system as do the most primitive central conductors from the trunk.

It should be noted here that a certain amount of locomotion may be acquired by an amphibian embryo by other movements than the S reaction as described above. The body may be flexed, for instance, and straightened by a series of secondary, vibratory movements. Such a reaction propels the animal on its side in a circle or spiral path. Also, a rapid succession of reversed flexures, in which no S reaction can be detected, may give swimming in a zigzag, erratic course. But normal, upright swimming in a direct course is, according to my observations, attained only through the perfecting of the S reaction and its performance in series.

As already suggested, this development of the swimming movement is of interest from the point of view of animal behavior. We now see that swimming, which may be regarded as instinctive in these forms, arises as the elaboration of the simplest known reflex in the embryo, the contraction of the most cephalic trunk muscles. Certain forms of the flexure, such as the U reaction and the coiled reaction, do not seem to be in the direct line of the development of the swimming movement, being simply intensive or tetanic forms of the ordinary flexures. On the other hand, the other types of flexure develop in a regular order and in a remarkably constant manner into the movements of locomotion. Now none of these simple flexures can be regarded as having any value as trials, since the Diemyctylus swims perfectly upon leaving the egg membranes in the normal course of development, and within them it can gain no practical experience for swimming out of movements of any sort. Instinctive swimming, therefore, and the simplest reflex alike, are inherent in the neuro-muscular system of the embryo, and while the former develops in a regular order out of the latter the movements themselves, which conform to this order, can have no selective value. The question naturally follows whether in forms which do not admit of such early experiments, such as birds, many quadrupeds and primates, the various forms of locomotion, as well as other forms of behavior, which, in a greater or less degree, appear to develop out of a series of trials, may not conform to the same law. It seems altogether possible that in such cases, also,

the so-called erratic movements may have only a trophic value. As such they would be essential to the perfecting of movements, but would have no directive value in the development of responses.

If, moreover, this hypothesis is valid for the ontogenetic origin and development of instinctive behavior it would seem plausible, also, as a theory of phylogenetic development. Its application to phylogenesis, though, would clearly be in opposition to the idea, which is accepted by various psychologists, that instinctive behavior has somehow been reflected back into the race from the intelligent type,—or, psychologically expressed, that instinct is a phylogenetic derivative of intelligence. For the latter hypothesis, I am not aware that there is any direct, experimental proof, while we do see, in such vertebrates as Amphibia which admit of early experimentation, instinctive behavior (locomotion) developing directly out of the simplest known reflex. However, while we seem to have a definite conception of the psychic parallel of the former (instinct), the concept of the psychic parallel of the latter is much less definite, and largely disregarded by psychologists. Yet it would seem that in the ontogenetic developments of the psychic life of Diemyctylus there must be quite as definite a reflex psychosis concomitant with the earliest and simplest reflex as there is an instinct psychosis with the later instinctive behavior in the form, for example, of locomotion; for, although the neuroses of the simple reflex are evidently not as elaborate as are those of locomotion, they are quite as definite in form. But, however this hypothesis of the relation of the instinct to the reflex may appeal to the psychologist, an adequate knowledge of the behavior of Diemyctylus must take into account the origin and development of locomotion from the simple reflex; for this reflex represents the simplest known physiological unit of the somatic neuro-muscular system, or of the somatic "action system." The relation of this unit to any of the more complex neuro-muscular processes is certainly an essential factor in the problem of behavior, or of physiology in the broadest sense.

In presenting the mode of locomotion of the amphibian embryo it is not my intention to antagonize the current explanation of the propelling factors of the swimming movement of fishes, ordinarily described as being, in effect, the same as that of a sculling oar. The latter explanation, so far as I am aware, is offered with reference to the adult fish, and it might not apply to an embryonic or

very young fish. Quite conceivably, the swimming movement might become modified during growth, in response to changes in body form, modes of feeding and other factors of behavior; and it is still quite possible that in the adult fish there is a cephalo-caudal progression of movement which is obscured by other factors of special adaptation.

This contribution should not be submitted without reference to the splendid work of Paton[7] on the reaction of vertebrate embryos. This is the only paper accessible to me that bears in any respect immediately upon the work in hand. Paton's contribution, however, is chiefly upon the development of fishes, with merely a reference to Rana and Amblystoma, and is particularly devoted to the spontaneous movements. Such movements would seem to be much more common in embryos of fishes than in embryos of Diemyctylus. The latter, during the early phases of irritability to touch, may be under observation for hours without making a perceptible spontaneous movement of the trunk, cardiac and branchial movements not being taken into account in my work.

My approach to the problem of physiologico-anatomical correlations in the development of the neuro-muscular system of vertebrates differs materially from that of Paton's method. Paton undertakes "to determine in a general, but not in a specific way" how far the reactions are dependent upon "the functional activity of a nervous system" and dismisses the study of specific reactions as impracticable, on account of the "apparently conflicting" data; but my work clearly demonstrates that, in response to the stimulus employed in my experiments, embryos of Diemyctylus have a very definite and regular mode of response, during certain phases of development. In fact I have yet to find the first individual that, through any considerable period, reacts contrary to the mode described in this paper, that is to say, no embryo has yet come under my observation that regularly moves its head toward the side touched when the stimulation is on the head. Nor have I found a single embryo that, observed for a considerable period, has not fallen under one of the three types which I have here described.

[7] The Reaction of the Vertebrate Embryo and the Associated Changes in the Nervous System. *Mittheilungen a. d. zoölogischen Station zu Neapel*, Bd. 18, Heft 2 u. 3, 1907.

THE RAISED BEACHES OF THE BEREA, CLEVELAND, AND EUCLID SHEETS, OHIO.[1]

FRANK CARNEY.

INTRODUCTION.

A Moravian missionary, Rev. John Heckewelder, came into the Tuscarawas valley, Bolivar county, in 1762. He traveled much throughout the State in his labors with the Indians, and in

[1] Presidential address read before the Ohio Academy of Science at the Granville meeting, November, 1908, representing work carried on under the direction of the Ohio Geological Survey. The author is responsible for the opinions expressed.

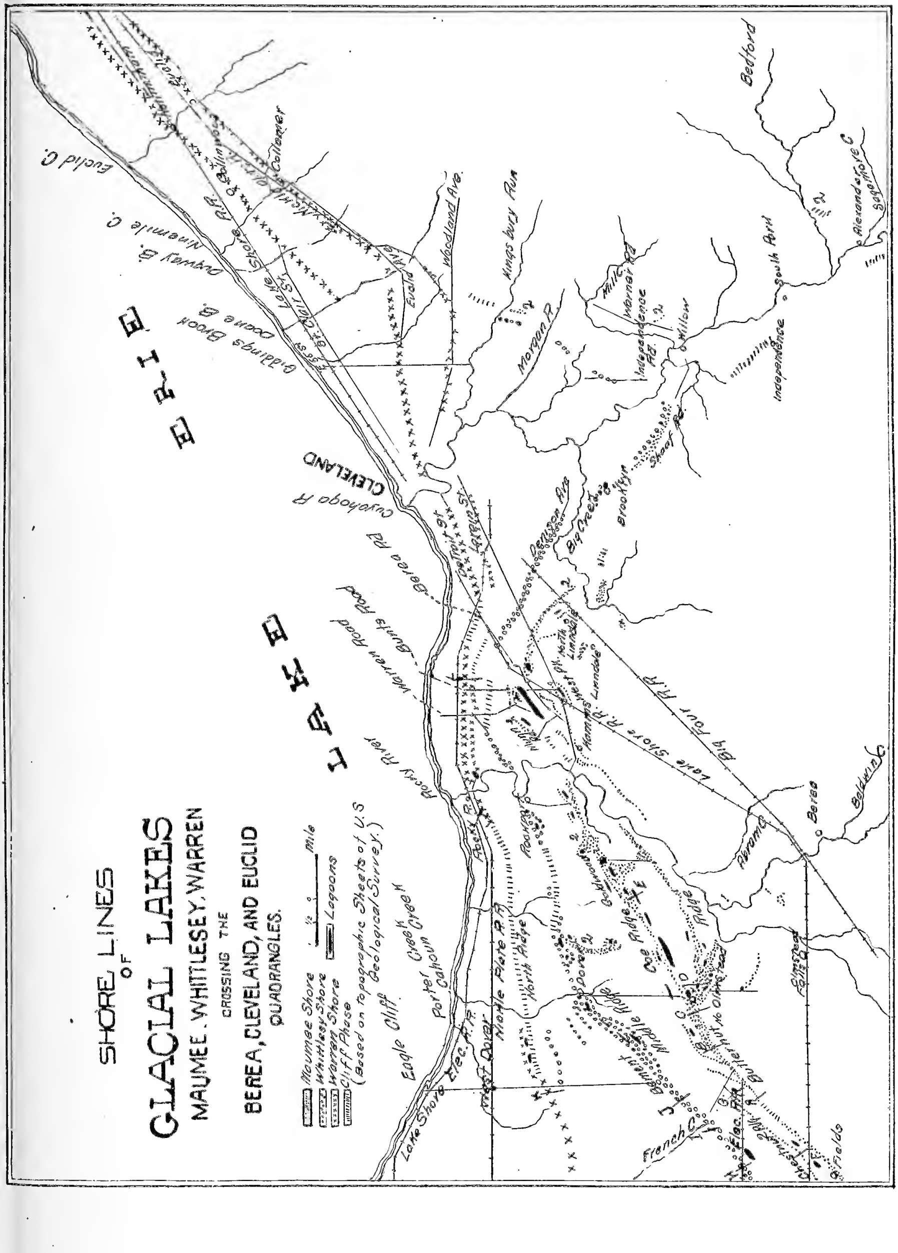
SHORE LINES OF GLACIAL LAKES
MAUMEE. WHITTLESEY. WARREN
CROSSING THE
BEREA, CLEVELAND, AND EUCLID
QUADRANGLES.
Maumee Shore
Whittlesey Shore
Warren Shore
Cliff Phase
(Based on Topographic Sheets of U.S. Geological Survey.)
Lagoons
Mile
LAKE ERIE
CLEVELAND
Cuyahoga R.
Euclid C.
Nine mile C.
Dugway B.
Doane B.
Giddings Brook
Collamer
Euclid Ave.
Woodland Ave.
Kingsbury Run
Morgan R.
Bedford
Alexander C.
South Park
Independence
Willow
Denison Ave.
Big Creek
Brooklyn
Berea Rd.
Detroit St.
Lorain St.
Rocky River
Warren Road
Lake Shore R.R.
Big Four R.R.
Berea
Baldwin C.
Abrams C.
Coe Ridge
North Ridge
Dover
Center Ridge
Butternut Ridge
French C.
Fields
Eagle Cliff
Porter Creek
Cahoun Creek
Lake Shore Elec. R.R.
West Dover
Nickle Plate R.R.
Elmstead

Fig. 1.

1796 drew a map of northeastern Ohio; on this map, he makes the first reference, so far as I can ascertain, to the Lake Erie shore lines. Accompanying the map is a brief description in which he refers more in detail to some of the deposits, now known to be of glacial and lake origin, about the lower part of Cuyahoga river.

In the second annual report of the Geological Survey of Ohio, published in 1838, on p. 55, Col. Charles Whittlesey refers to the beaches skirting Lake Erie. It would indeed be surprising not to find in these early documents references to the lake ridges—they are so conspicuous a feature of the landscape. The Indians selected these ridges for their paths, and the first settlers located their highways and dwellings on them. Colonel Whittlesey's comments are very brief.

The first even casual study of these beaches was by Sir Charles Lyell, the British geologist, in 1842; he followed two of the ridges for much of the distance between the Cuyahoga and Rocky rivers. He suggested methods by which they might be more correctly interpreted, lamenting that he did not have the time to ascertain whether fresh or marine shells were to be found with the gravels. He gave it as his tentative opinion that the "Middle Ridge"[2] (fig. 1) in particular appears to be subaqueous in origin.

In 1870, G. K. Gilbert studied the raised beaches in the Maumee valley; this work is probably the first rigorous study of shore-phenomena associated with ice-front lakes. Gilbert mapped the four beaches which indicated the levels of Lake Maumee and the succeeding bodies of water held up by the Erie lobe. Since his field of investigation was limited to the northwest counties of the State, he did not follow the beaches very far to the east nor to the north. Gilbert's methods of studying these ridges, as well as many of his conclusions, were entirely new to the science of geology; some of his interpretations he himself altered later.

The same volume which contains Gilbert's map on the beaches of the Maumee lobe, also contains J. S. Newberry's article on the Geology of Cuyahoga County; in this, Newberry devotes about four pages to the lake ridges.

In the succeeding volume of the Ohio Survey, A. A. Wright and J. S. Newberry published a more detailed description of these

[2] The discussion of these beaches can be followed to better advantage if you have at hand the three topographic sheets involved.

ridges between Elyria and Cleveland. Each ridge was traced for several miles at intervals; no attempt was made to give a detailed description of any particular beach.

From about 1890, the shore-phenomena of ice-front lakes has been given special attention by many trained geologists, either independent workers, State Survey men, or employees of the Canadian and United States Geological Surveys. The descriptions of, and references to, the beaches in the vicinity of Cleveland are numerous and have involved much labor in their correlation. The actuating purpose of each of these workers was the bearing that the ridges of a particular locality have on broader questions of the greater lakes' history; for this reason, we find very few close studies of any of the beaches.

The present investigation concerns the lake ridges of a narrow area; it attempts no contribution whatever to the larger problem of successive ice-front lakes. One of my purposes is the interpretation of the activities along present water-bodies from the standpoint of work done by water-bodies of the past. The activities of wave and shore currents of the present Lake Erie may be intelligently studied in the light of what these same agencies were doing when the lake was one hundred to two hundred feet deeper. At no place in the State can one find in such horizontal nearness, in more complete development, and in better preservation, the shore lines of former water-bodies.

GENERAL CONSIDERATION OF ICE-FRONT LAKES.

When the great ice-sheet attained its maximum development in North America, east of the Mississippi it extended beyond the divide of the present St. Lawrence drainage basin. This position was not reached by an uninterrupted progress. From the dispersion centers of Labrador and Keewatin the ice fed outward, sometimes maintaining a stationary front because melting and feeding were balanced, retreating when wastage was the more active, and advancing with the ascendancy of the feeding.

Wherever the great plain over which the ice was spreading sloped away from the ice, drainage moved freely; where, however, this plain sloped toward the coming ice, the water gathered, forming lakes.

The record of the bodies of water marginal to the Wisconsin

ice-sheet has long been known with much accuracy. As soon as the ice in its retreat came to a halt within the basins of the present Great Lakes, then frontal water accumulated; thus there were small lakes in the Michigan and in the Erie basins, while the remaining basins were buried beneath ice. These small lakes gradually expanded as the ice-cap diminished. So long as each lake maintained an independent overflow southward, it is evident that there had not been disclosed, in the area between these lakes, an altitude lower than the altitude of the overflow channels. As soon as any lower point was disclosed by the retreating ice then the marginal lakes coalesced and continued to drain southward by the lowest col reached. Frequently long intervals of time marked the spacing of these periods of retreat. It is this fact that makes it possible today to deliminate the extent of these temporary lakes. A time did come, however, when the whole front of the gradually receding ice-sheet was skirted by a body of water which reached the ocean by a single overflow channel. The first of these more expanded bodies of water overflowed by way of the Illinois river, past the present location of Chicago. A lower outlet was revealed when the ice withdrew from the Mohawk Valley area; then this great marginal lake reached the Atlantic by the eastern outlet.

The succession of ice-front lakes, as we today read descriptions of their succeeding overflow channels, include so many positions that we fail to comprehend the time involved. We feel that the shore line of any particular one of the present Great Lakes, as Superior, represents a long time period. We have difficulty, perhaps, in realizing that Lake Whittlesey, or Maumee, probably endured quite as long as the present Lake Ontario. When, however, we compare the rock cliffs now bordering the shore of Lake Erie, the constructed beaches, the barriers, the lagoons isolated by development of new bars, the dune sands reaching inland from the shores, with the identical phenomena of these lakes of the past and see how little they differ in scale, in spite of the denuding agencies that have operated upon them since they were formed, then we can better comprehend the very appreciable time intervals represented by the successive stages in the past history of the Great Lakes.

The shore of Lake Maumee in the vicinity of Cleveland was irregular because of the embayments occupying the Rocky river

and Cuyahoga river valleys. The arm of the lake extending southward into the former valley was crescent shaped, the western being the shorter of the two segments; but the prevailing winds, by constructing spits and bars, gradually brought that part of the shore into alignment with the general direction of the beach. A more detailed discussion of this is given later.

The valley of Big creek also formed a small bay during the early part of this lake stage; here again, on its western side, bars gradually developed and straightened the shore line.

The mature Cuyahoga valley was occupied by water of the Maumee level, reaching southward through the entire length of the Cleveland sheet. This arm was the drowned portion of the Cuyahoga valley, for the tributaries of which the lake constituted a local base level into which they spread deltas.

The shore of the Lake Whittlesey stage shows no evidence of a bay in the meridian of Rocky river; there was a slight curve in its outline where the water fronted the lower part of Big creek. In the Cuyahoga valley, however, this stage appears to have extended southward through the Cleveland sheet; its altitude is recorded by terraces cut into the deltas of the preceding stage, as well as by the extension of these deltas during the existence of Lake Whittlesey.

The Warren shoreline is characterized by but one embayment, that occupying the Cuyahoga valley which was ponded the entire length of the Cleveland sheet.

THE DEVELOPMENT OF SHORE LINES.

The processes involved in the development of shore lines are chemical and mechanical. The chemical factor is not of great consequence, though from one point of view it demands attention; the mechanical processes are really the ones that need consideration. Winds impel the water into waves and currents producing primarily two movements, on-shore and along-shore. The effectiveness of each movement is controlled directly by the velocity of the wind and the nature of the coast.

The work accomplished by these agencies is influenced in the first place by the nature of the material which the waves are attacking; if the coast is rock it yields less readily than do unconsolidated deposits; in the second place, by the profile of the beach

and off-shore slope. Ultimately these agencies under normal exposure to waves will bring about a fairly uniform and constant profile which is a gentle long slope into deeper water. The time required for a given body of water in a particular locality to produce shore line structures, depends very largely upon the original outline of the coast: if sufficiently irregular, and if it yields quickly to these denuding agencies, a supply of material will be at hand for constant work.

It is in the production of this material that the chemical process figures. In the presence of water, chemical disintegration is facilitated. This is important even when the coast being attacked consists of unconsolidated deposits. The basic elements of glacial drift break down more readily, leaving the acidic for distribution by waves.

But the more effective work in the preparation of material is accomplished locally by the waves of translation which erode the shores producing bluffs, that in turn are under-cut by wave-impact and the tools the water has in it. This on-shore movement of water likewise grinds the constituents of the beach, rounding and diminishing the size of all the stones. The along-shore movements also do much attrition work. Furthermore, as the waves of greater size break off-shore, they pick up bits of rock, dashing them again to the bottom, thus continuing the work of attrition begun nearer shore.

All this material is being distributed likewise by the water. Beach ridges represent the ascendency of the work of water moving on-shore over that accomplished by the water moving outward, that is, the undertow. Whenever the dash of oncoming waves drives material up the slope beyond the effective reach of the undertow, that material becomes part of the beach ridge. The ridges represent the work of unusually strong and more directly on-shore movements; an equally powerful on-shore wave, striking the coast obliquely, is not so effective in constructing ridges. Since the beach ridge, then, represents a differential of these quite opposing movements of water, it follows that the shape of this ridge is also the result of this difference. The undertow cannot carry any save the smaller bits of rock, and only the finer portions are carried very far off-shore. Material in suspension is always the finest product of destructive work and will be taken farthest from the shore line. The front slope of a beach ridge has a long gentle

gradient, save at the edge of the water, where, for a short horizontal distance, the angle is sharper; the back-slope often has a short, sharp angle, and stands more conspicuously above the coast (figs. 2, 3).

When the waves do not strike the shore directly, the oblique movement sets up an along-shore drift; this along-shore drift is a more active distributing agent when the coast is parallel to, or but slightly transverse to, the direction of the prevailing winds. The outlines of these high-level lakes were in general concentric with the present Lake Erie, the shore of which is well exposed to the sweep of the prevailing west winds. It is due to this relationship that headlands have been removed and their products distributed to the east.

Where an angle of water extends into the land, we generally find a *spit* gradually growing out across this reënterent from its windward side. The along-shore movement of water distributes material in a straight line unless some stronger force tends to deflect the line of deposition. Such a deflecting force is present when we find translatory waves passing landward through the deepening area of the bay; then the spit is bent inward in the shape of a hook. As the height of the spit increases from its tied end, the effectiveness of this deflecting movement is tempered, and we see in consequence, that the spit continues its development in a straight line, leaving the hooked portion as an irregularity on the back slope of the spit; when the bay has been completely shut off, this constructed form is called a *bar*. It not infrequently happens that spits are developed outward from either side of a bay, sometimes uniting, and sometimes passing each other, thus isolating the bay.

In the construction of spits from the windward angle of the bay, sometimes intervening areas are isolated and form lagoons. These lagoons may be developed in series, as when the spit terminates in a hook and later continues to grow forward; more often, however, the lagoons have long axes parallel with the trend of the bars.

Through the interference of shore currents, such interferences often arising from deflected movements of water, the loose materials instead of being carried continuously parallel with the shore, are so deposited as to form a cape which gradually grows out into the water. This constructional form is termed a *cusp*.

When the shore slopes gradually into deeper water, the higher

waves break some distance from the shore; the work then done is similar to that accomplished by strong waves breaking at the water-margin, that is, material is piled up; this piling up of detritus in deeper water develops a *barrier* which is, in reality, a submerged beach ridge; barriers therefore, are parallel to the shore. Much of the material which enters into the construction of barriers has been carried back from the shore by the undertow. In time the barrier grows higher, and accordingly interferes with the velocity of along-shore currents, causing the water to drop some of the load it may be carrying. From this time on, the barrier grows through these two methods; it may ultimately rise to the surface of the water and eventually form the shore line proper; when this happens, the space between the beach ridge or cliff, and the barrier, becomes a lagoon.

We sometimes find a cusp fringed by a barrier; the process of its development is identical with the method above discussed. Between this barrier and the cusp, a lagoon may appear. The barrier may or may not border the entire cusp.

Islands, and shallow places due to irregularities of the lake bed, interfere with the movements of the water; the former undergo wave and current erosion, thus supplying materials for the construction of spits, etc.; the latter, when rising sufficiently near to the surface of the water, may check its velocity and thus grow upward through the accession of deposits. With the continuation of this process, an island may appear, and from it spits will develop with the course of the prevailing winds.

LAKE MAUMEE LEVEL.

I will describe these beaches from west to east across the Cleveland area (fig. 1). The altitude usually assigned to the Maumee level ranges from 765 to 785 feet. This lake was about 200 feet deeper than Lake Erie. Two stages are indicated by a higher and lower beach varying 15 to 20 feet in altitude.

From Fields east to the Elyria traction line this shore consists of a cliff and terrace cut in the glacial drift (fig. 2, A); the terrace bears some gravel; thence to the vicinity of Kamms, which is just east of the Rocky river, it is made of gravel and sand. In places this beach has a steep back-slope; throughout most of the distance, the front slope rises from 15 to 20 feet (fig. 2, B, C, D).

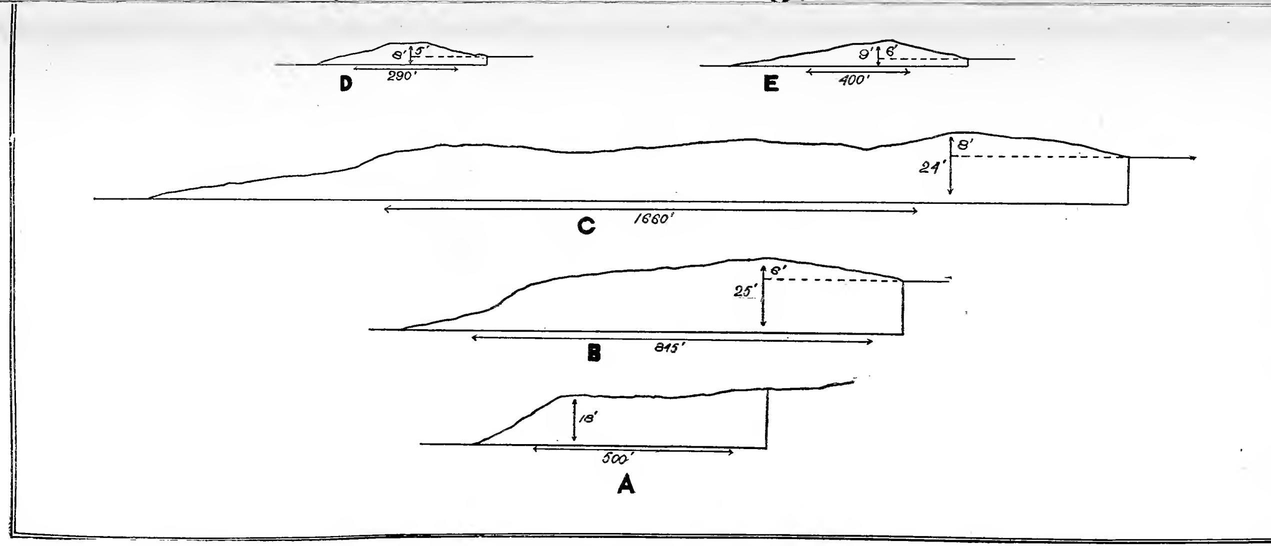

FIG. 2. Cross-sections A–D belong to the upper Maumee level; E–G, to the lower Maumee level. The location of the cross-sections may be found on fig. 1.

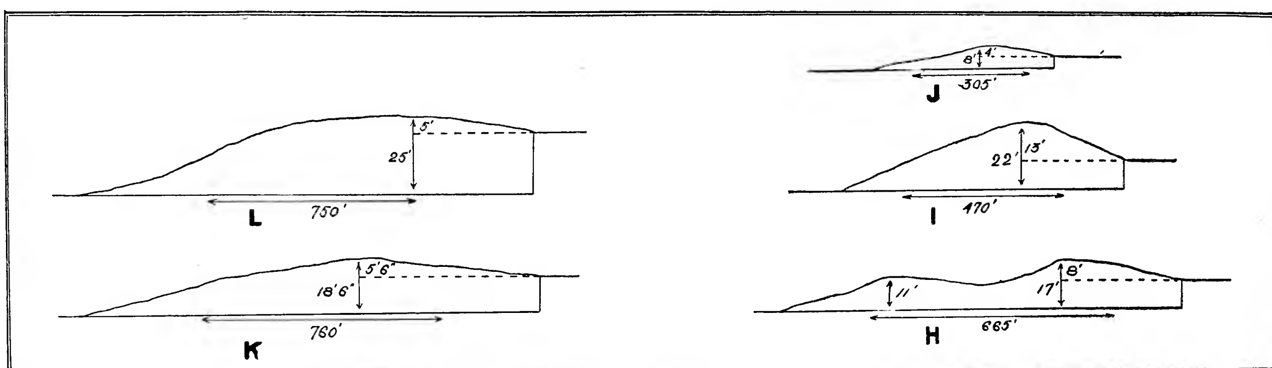

FIG. 3. Cross-sections H–J belong to the Whittlesey level; K and L, to the Warren level. For location of each cross-section consult fig. 1.

South-east from North Olmsted its constituents are fine to coarse sand, and less gravel. For a long period the region about North Olmsted must have formed a point or cape in the shore line as it marked the western limit on the Rocky river embayment. There is evidence of vigorous wave-action here; a few rods south of the corners at North Olmsted is a gravel ridge with a front-slope 3 feet and a back-slope 7 feet high, and containing stones as large as 3 inches in diameter.

The first barrier built in this embayment is traversed by a south-east-trending road connecting the two north-south highways south-east of North Olmsted; this barrier is about three-fourths of a mile long and consists chiefly of fine deposits. Its discontinuance westward where we would normally expect it to join the main ridge may be partly due to removal by erosion; eastward it flattens out and disappears within about one-fourth mile of the Rocky river channel. Inland from this I found no evidence of a beach, a condition due to the very low gradient and the consequent wide zone of shallow water. About one-half mile north of the west end of this barrier there is another ridge, terminating near the creek in a slightly recurved spit, apparently subaqueous in origin but later marking the shore line for a relatively brief period, after which it was gradually isolated by the development from the western shoulder of the embayment of still another spit.

The road extending south-east from North Olmsted traverses this bar which tended farther to shut out the Rocky river embayment; this bar is coarser in texture than the bar above described, and encloses in its rear several lagoons which were developed consecutively from west to east by the hooked growth of spits as the bar extended farther across the bay. This ridge continues to the edge of the present channel of Rocky river, and there is some evidence of it eastward from the river.

Returning to the shoulder in the main shore line at North Olmsted, we find at the present time a pronounced cliff, swinging at first slightly to the south and then continuing directly east. Between this and the bar last described, there are several marsh areas or lagoons, decreasing in number and size eastward, and each representing an inward bend or temporary hook-terminus of the spit. While this originated as a spit growing into the bay, it came in time to be a typical wave-constructed beach; its front slope is

gentle, rising in altitude from 10 to 14 feet; the back slope is nowhere very pronounced, owing to the leveling-up of the lagoon depressions. The beach averages about 10 rods in width; in places, however, the back slope is so slight as to make exact measurement impossible. Over the first mile of this beach, a highway extends, branching at the river into one road running directly north and another skirting the river channel; this latter road continues on a slight gravel ridge, the most pronounced phase of which lies to the east of the highway next to the river cliff. It is probable, however, that the complete development of the shore-ridge in this locality may not now appear for the reason that on its eastern side the river has undercut much of its width. After the first half mile, the beach lies entirely to the east of a highway, at which place it has been worked for a long time as a gravel pit; this is on the farm of W. F. Schultz. Proceeding, the highway again strikes the ridge which at no point for the next mile rises more than 5 feet above the general level; it discontinues within the next one-half mile, terminating directly south-east of Goldwood; but on the opposite side of the river about one-half mile south of Puritas Springs, we find this beach again, and can follow it without a break to within one-eighth of a mile of Kamms, where it becomes a cliff, cut in the Cleveland shale. A few rods east of Kamms, the cliff phase changes to a low gravel ridge which continues through and east of West Park.

In the vicinity of West Park the water deepened so gradually to the north, that no beach ridge was constructed; low spits, however, were developed, apparently of the barrier-type in origin, which were later somewhat modified as the on-shore waves succeeded in forming a true beach. One such spit turns sharply northward of the intersection of Lorain and Davisville streets. This relationship of ridges accounts for the slight lagoon just south-east of the corner at West Park. Other lagoon areas were developed within a mile north of this area, the principle one of which lies between the Berea and Warren roads; apparently, this latter lagoon represents a slight bay which was later enclosed by a barrier.

The West Park area presents some complexities in shore structure largely because of its proximity to the Big creek embayment. This embayment was in time completely shut off through the successive growth of bars.

The first of these spits ties to the main shore in the vicinity of Linndale, extending north-westward about one-quarter of a mile; this has a pronounced development, being from 5 to 15 feet in altitude; it consists of well worn gravel and sand. No spit correlating with this was found on the opposite side of the bay.

Extending southward from Lorain street, is another spit from 2 to 5 feet in altitude, and for about one-half mile continues a few rods west of Bosworth road, after which this road follows the ridge to Bellaire road, in North Linndale. The western tributary of Big creek runs parallel with this spit for about 80 rods.

Some scattered ridges of gravel exist south of Big creek on the opposite shore of this embayment.

After the Maumee lake level had finally established a continuous shore line across the valley of Big creek, the beach-forming agencies must have worked uninterruptedly for a long period. From the intersection of the Big Four track with the Berea road north-east of Rockport, eastward to the present channel of Big creek in the vicinity of the West Shore railroad, the shore is a beach-ridge and cliff averaging about 23 feet in height and having a sharp front slope. In the north-west part of Rockport village are depressions representing a lagoon developed in the growth of this beach, but eastward to the West Shore railroad, the ridge, simple in construction, consists of ordinary shore gravels. At the West Shore railroad, however, it divides; one of these divisions terminates on the edge of the creek bluff, but probably reappears again in a slight gravel ridge overlying moraine, south of the creek; the other arm, later in development, trends south-east, terminating in the bluff near West Park cemetery.

For the next one-half mile, I was unable to find any gravels, but the shore line appears to be indicated by a cliff cut in the moraine; nearing Brooklyn, however, beach gravels again appear. Street grading and other structural work have so modified topography here that one can not decide whether the ridge through a part of Brooklyn is of barrier origin, or of regular beach construction. South of Brooklyn, as the Schaaf road diverges to the east, the Maumee level is plainly marked; the highest part of the beach here bears much sand, suggesting subaqueous origin.

East from this point the higher Maumee level is not definitely marked. North of Independence, the slope has been steepened possibly by wave-work, and possibly by stream-work when the

glacier extended southward into the Cuyahoga valley, ponding the drainage which escaped westward along the edge of the ice. About a mile north of Willow along the Warren road, there is beach gravel, and north of Kingsbury run the rock slope appears to be wave-cut at an altitude correlating with this lake stage.

Returning to the western edge of the Berea sheet, we find a few rods north of this shore line what was probably a barrier, and later a beach, followed now by a highway, locally designated "Chestnut ridge". This ridge is about 15 feet below the shore line above described; it consists generally of fine sand; is from 4 to 6 rods wide and rises 8 feet on the average along its front-slope, which is very gradual (fig. 2, F, G). Between Chestnut ridge and the beach of the higher Maumee level, the interval is very mucky, indicating a former lagoon condition; to the east and north, this ridge blends gradually into the general level. Between this point and North Olmsted, two slender ridges, tied at their western ends to the beach of the higher level, trend with the old shore line.

From North Olmsted to the edge of the present river channel directly west of Kamms, is a sharply defined beach slope changing locally into a constructed shore ridge. Throughout this distance we have the permanent shore line for the lower Maumee level (indicated by 2 on fig. 1), marking the position of the water after the Rocky river embayment had been completely closed; the back slope of the ridge descends into extensive mucky areas which indicate the swampy condition that prevailed for a long period after the embayment had been shut off. Market-gardening is the chief industry in this section at the present time. The most conspicuous spit developed in the process of enclosing the Rocky river embayment is the broad-based ridge extending southward from Goldwood; opposite the end of this, extending northwestward from the other shore of the bay, is a correlating spit; apparently the two approached quite closely but have since been separated by erosion.

Proceeding eastward from Goldwood this shore line takes on more and more the form of a constructed beach, varying in width from 4 to 15 rods, and in height from 12 to 24 feet. Near the river it is slightly modified through erosion.

Another feature of this level of the Maumee stage is found in the off-shore bars which are not strictly of the barrier type. The second highway east of North Olmsted, running to the north,

passes along a north-south ridge of gravel and sand. Reaching eastward from the termini of this ridge are compound spits that represent the work of west winds. This bar and its appended spits with their like orientation indicate a shallow place in the water occasioned probably by a ridge of glacial drift. Smooth-surfaced till, rather stony in texture, is found in the fields east and west of this ridge. Wells sunk in the ridge also penetrate drift, but throughout its whole extent the ridge is covered with gravel from 5 to 14 feet in thickness. The spits that have grown from the ends of this ridge present several interesting features, especially in their constant trend to the east, in their gradual variation in texture from coarser gravels to fine sand eastward, and in the lagoons formed by the development of secondary spits from the windward side of the angle made by the main bar and the spit already developed.

A short one-half mile north-east of Goldwood is a cusp fringed by a barrier. The cusp is about 50 rods long; between it and the barrier is a lagoon.

Eastward towards the river, just before crossing the road which leads north to Rockport, is a short barrier with a lagoon in its rear. From the intersection of the Rockport road with the main shore, another ridge extends north-eastward; this, throughout nearly the whole of its one-half mile length, shows a strong development, in places 4 to 6 rods wide on top, and having a sharp back-slope.

Continuing eastward along this lower level of the Maumee Lake, we find on the opposite side of the river, west and north of the Rockport race track, a short slope due to wave work on the shales thus forming a cliff. For some distance this shore line is indistinct, but reappears about one-half mile northeast of Munn road, in a strongly developed gravel ridge which swings due east after crossing Warren road. It shortly blends into a low ridge of clay. The interpretation of this clay ridge was puzzling for some time; it is plainly not of glacial origin, and is so free from gravel or other normal wave-worn products that a shore line genesis did not suggest itself. In this vicinity, the Cleveland shale bears scarcely a veneer of glacial deposits. Wave action in consequence has attacked the shale, and because of the very low slope of the lake basin, cliff cutting did not take place. The shale was ground off by the waves and piled in a low ridge, so slowly

that weathering proceeded, it is thought, to a considerable extent before Maumee Lake fell to a lower level.

Going south from Warren road, along Brown road, one crosses two other slight gravel and sand ridges which alternate with lagoons. The southernmost of these formed the north shore line of the lagoon bay, already mentioned, which Brown road crosses before reaching Berea road.

Farther eastward, I have not noted any distinct shore-ridges correlating with this second Maumee level, except the possibility of such a ridge being indicated by the shore gravel extending south-eastward from the intersection of this beach with the West Shore railroad just north of Big creek. The front-slope of the beach along Schaaf road shows some evidence of being modified by the water of this lower level. The Tinkers creek delta has a cliff and terrace which apparently correlates with it. Northeast of Willow, on the slope east of a brick plant, are gravels at the proper altitude. And east of 87th street, between Union avenue, and Kinsman road, is another area of possible lower Maumee shore deposits.

LAKE WHITTLESEY LEVEL.

The altitude of this shore line is approximately 735 feet, or about 30 feet lower than the preceding stage. From the western border of the Berea quadrangle to the Cuyahoga river, it is practically unbroken, and for the major part of this distance consists of a gravel ridge, in a few places one-quarter of a mile wide, enclosing lagoons. The Cleveland, Elyria, and Western Electric railway enters the Berea sheet on this ridge, but after traversing it for a few rods, swings directly eastward to the shore ridge of the Maumee level.

Cross sections of the western part of this beach are shown in fig. 3, H–J. The compound characteristic of the ridge is apparent in section H. The low front-slope condition here indicated continues to characterize the ridge north-eastward as far as Bement; from Bement to Dover, the ridge is found in its most complex phase; through most of this distance, the outer slope is longer than shown in section J. The ridge top is much broader and for the second half of the distance we find a series of ridges alternating with longitudinal muck basins.

From Dover eastward to Rockport the ridge consists of gravel with a short front-slope rising 20 to 22 feet, and a back-slope dropping not more than 7 feet (fig. 4). The compound form of the ridge observed west of Dover is much less charactersitic of this portion; nearing Rockport, however, I have noted a few former swamp areas. The shape of the front-slope for several miles here indicates cliff-development, at the western portion in shale, and eastward, where the shore line crosses the buried Rocky river channel, in drift.

Crossing the Rocky river, the course of this beach is indicated for about one mile by Hilliard road, but at the intersection of West Madison avenue, the beach swings directly to the east, and changes from a gravel ridge to a cut cliff shown in the steep slope just north of this avenue. From Ridgewood avenue, eastward to the Lake Shore railway, the course of the beach is not definite; but upon crossing the Lake Shore, it comes in once more in its beach-ridge phase and thus continues to the neighborhood of the intersection of Fulton road and Denison avenue. From Lorain street almost to Fulton road, this ridge originated as a spit developing into the Cuyahoga embayment, and for over one-half of the distance, for some period of time, appears to have formed the shore while the other half apparently was still subaqueous.

From Fulton road to the western part of Brooklyn, whatever development this beach had obtained has since been obliterated by the erosion-work of Big creek. Its course through Brooklyn is somewhat doubtful because of street grading and other destructive work. The best exposure of the beach-ridge in this vicinity is along the west side of Broadview avenue just east of West 25th street; for about 80 rods the beach thus continues; it then swings southward across Broadview and flattens out. A short distance farther to the south I noted a wave-cut cliff parallel to Scarsdale avenue, which turns southward crossing Roanoke and Tate avenues. Beyond this point the shore of Lake Whittlesey was at first parallel to, and later coincided with, the lower beach of Lake Maumee. This horizontal coincidence has given the lower Maumee beach a steep front-slope, the difference in the level of the two lakes measuring the vertical distance through which the older beach may have been over-steepened. On the opposite side of the Cuyahoga river, about one and one-half miles north of Willow, we find parallel with Independence road, a bar one-half

mile in length; the southern part of this is nearly north-south in direction, but the northern half swings eastward in conformation with the outlines of the Cuyahoga embayment. Sand and gravel of contemporaneous development were noted along 59th street,

FIG. 4. Looking eastward along the Whittlesey beach one-half mile east of Dover

FIG. 5. Looking eastward across the Warren shore line at first highway south of West Dover; the cliff is here cut in shale.

south of Harvard avenue. For some distance northward this beach could not be definitely mapped since this interval has been worked over in the street development of Newburg, but for a short distance between 80th street and the Pennsylvania railroad,

there is a low ridge of gravel conforming in altitude with this lake level. For over a mile to the northward, I have not mapped any gravel or sand interpreted as representing Lake Whittlesey, but just south of the Fairmount reservoir, and parallel to Baldwin street, there is a low sandy ridge which indicates this shore.

From this point eastward I was unable to satisfy myself that the rock escarpment gives any evidence of wave work that definitely indicates the Whittlesey level; there are scattered salients which bear indefinite notches that may possibly indicate cliff-cutting of this shore; some of these benches may also be explained as the result of differential weathering. It seems preferable to state that the rock cliff which continues north-eastward from Garfield's monument for some eight miles is due to denuding agents in operation long prior to the ice invasion, and has since been altered slightly by the wave work of both the Maumee and Whittlesey levels.

LAKE WARREN LEVEL.

Lake Warren marks a vertical subsidence of the Whittlesey level; the drop is about 50 feet. The evidence west of Rocky River on the Berea sheet suggests that the subsidence was brought about in a very short time, but eastward from Rocky river there is an intermediate beach of slight development suggesting a gradual subsidence of the Whittlesey to the Warren level. This intermediate stage averages 20 feet above the Warren beach proper. From the Rocky river, to Ridgewood avenue, it is practically parallel to Detroit street, and consists of a low broad ridge of fine sand and gravel as far as Arthur avenue, while eastward the level is marked by a cliff cut in the Cleveland shale. The same ridge appears again along West Madison avenue, in the vicinity of 81st street; turning to the northeast, it crosses the Nickel Plate railroad, thence more directly east it crosses West 25th street, a short distance south of Lorain street. On the east side of the Cuyahoga the general direction of this beach is indicated by Woodland avenue, which follows the ridge for over two miles.

Just west of the Berea sheet in Lorain county, the Warren shore bears sharply to the north. This point of land extending into the lake acted as a wind break to the shore directly east. In consequence of this, the first two miles of the Warren shore on the Berea sheet consists almost entirely of sand and very fine gravel; the

beach contains a slight terrace (fig. 3, K), a cliff that averages about 20 feet, and for most of this distance, is a low ridge. A few rods east of the north-south road connecting West Dover and Bement, the Warren level is marked by a cliff cut in the shales (fig. 5), and this phase continues eastward for a little more than four miles. Contemporaneously with the development of the first mile of this cliff, off-shore deposits gradually widened the beach; throughout part of this distance, two or more barriers developed, giving rise to intervening depressed areas where marshes have persisted till the present time. A cliff and terrace characterizes this shore where it crosses the buried Rocky river.

Between the sandy beach on the west side of the sheet and the till terrace marking the site of old Rocky river, the interval of shales bears locally a few feet of glacial drift. Eastward of Cahoun creek, there is slight evidence of gravel accumulations at the base of the bluff.

Commencing three-fourths of a mile west of Rocky river, the top of the bluff bears a beach ridge, its crest rising three to four feet. Nearing the river, the ridge becomes composite, inclosing lagoons. Directly east of Rocky river, a cusp, developed from this beach, extends northward from Detroit street across the Nickel Plate railroad. For about two miles this beach consists of a sand ridge locally composite, and from 40 to 80 rods in width. Near Highland avenue, the beach gravels present a sharper front slope (fig. 3, L). Just east of this avenue, the shore line swings slightly southward, changing to a cliff cut in the Cleveland shales. In the vicinity of West 100 street, the Warren level is again indicated by a wide sandy beach, in places, reaching from Detroit avenue southward to Franklin avenue.

On the east side of the Cuyahoga, excepting about one mile west of Wade Park, the Warren level is marked by the Euclid avenue beach. From the vicinity of East 65th street, to the campus of the Women's College of Western Reserve University, the Warren shore is found north of Euclid avenue. Eastward as far as Collamer, a beach-ridge condition continues to the eastern edge of Euclid sheet. There is evidence that the Warren level did some wave-cutting in the shales, developing a gravel-bordered terrace that is wider in some places than in others, the control being a matter of stratigraphy. East of Euclid, the cliff-cutting work of this lake was more pronounced.

In the vicinity of the intersection of Ansel road and Superior avenue, I noted a conspicuous development of rather fine sand. Sand of the same level may exist westward, but on account of extensive building operations, tracing it was not at all satisfactory. Eastward from Doan creek, however, this broad, low ridge of sand may be followed without a break to the intersection of Penobscot and St. Clair avenues; from this point eastward, St. Clair avenue is located on this ridge of sand and gravel, and continues thereon to Nottingham. For three-fourths of a mile east of Nottingham, the gravel ridge is but slightly developed, but reappears again just before St. Clair avenue crosses the Lake Shore tracks; thence for one and one-fourth miles the gravel ridge swings a little north of the avenue and continues to the edge of the Euclid sheet. From Nottingham eastward, this ridge is not over three feet high, even where it is best developed, but west of Nottingham, the ridge in places is 5 feet to 10 feet high, and contains some rather coarse gravel.

This St. Clair avenue beach ridge is about 30 feet lower than the proper Warren level; its shape and continuity suggest a lake stage. West of the river nearly to Edgewater Park there is much sand and fine gravel at the same altitude. If, however, Lake Warren declined slowly, or by short stages, it is probable that the St. Clair ridge is only a barrier beach.

LIFE RELATIONS OF THESE SHORE LINES.

The flat region bordering Lake Erie has been likened to a coastal plain. There are several reasons for seeing a similarity. In the first place, the escarpment due largely to inequality of rock texture serves as a border for the low smooth strip that belts the lake. This flat bordering strip, as we have seen, is a terraced lake plain. Furthermore, the successive lake-stages have given the streams corresponding local base-levels, hence they have had a drainage history very unlike that of coastal plain streams. Organisms, flora and fauna, have been influenced by this particular physiography with its stretches of gravel ridges, rock cliffs, wide strips of sand and marshes, and extensive clay areas. And man, both Indian and white, dwelling here, has also experienced physiographic reactions. It is our purpose to look briefly into some of man's responses.

These old shore lines in their development witnessed the usual shifting facies of plant habitats, developing societies, and in time families and communities, working out the usual history that always takes place slowly under a changing environment. The ecology of modern shore lines under like climatic conditions must be very similar. Each stage of these high level lakes involved a great lapse of time. Some indications of this time are seen in the numerous swamp areas, many of which had not been eliminated by natural processes when the white man came into the area.

As soon as a given level of the lake gave way to a new and lower level, the deserted beach, as well as the area recently covered by deep water, were spread over by plants in their normal struggle. From the standpoint of the farmer, the plant history of this land is of importance. Residual rock alone does not make a fertile farm. He ploughs the soil which is reduced rock plus the remains of organisms; usually the more of this latter addition the better is his soil. A ridge inhospitable to plants is made artificially hospitable to crops only with the greatest of labor.

Beach societies were never prolific, for here flora always has a struggle and even after the withdrawal of the water insuring a static condition of the beach, the plant societies multiplied very slowly. For this reason humus accumulated slowly. Relatively, then, beaches were never fertile. The sand areas always associated with beaches, either through the development of spits, cusps, or deltas, have a more abundant flora, in consequence of which they have become richer for cultivation. The prolific plant life of lagoons develops an almost ideal soil. Many lagoons are found about the angles of embayments and between barriers and shores; these make rich lands.

Another relation of these shore lines, passive but of importance in the development of the region, is seen in their use by the Indian for trails and the white man for highways. In consequence of this influence, the farms front the shore-ridges, and the houses, in general, are placed on the front-slope where quick and effective drainage is best assured. The shape of the older farms, longer or shorter as the shores converge or diverge, again shows an influence of these successive lake levels.

Furthermore, there is observed in the agricultural evolution of this region a tardy adaptation to natural conditions. The first farmers here were emigrants from New England and carried on

general farming, extensive in its application. Land was cheap and there was plenty of it; population was sparse, hence markets were limited. Only the old staple lines of grains and fruits were cultivated. Even in a generation, the descendants of these New England emigrants learned that the muck lands associated with the ridges were especially adapted to the growth of onions; further than this, I have not been able to learn of much ingenuity on the part of these aboriginal farmers. Gradually as more distant outlets were found, the first through the construction of good stage roads, later through the digging of canals and the stimulated lake-navigation, and finally through the building of railroads, agriculture became more varied.

More thought was given to adapting crops to the soil. The broad flats below the Whittlesey level were found better suited to the growth of vineyards; the soil here is clay, for the most part either glacial or residual of the old shales. We note in this region at the present time further diversity, particularly where a low swell of gravel breaks the usual clay; these slight ridges may be located, usually by an apple orchard three or four rows of trees wide, but awkwardly long.

With the increasing city population, a growth made up very largely of foreigners attracted by opportunities of labor, there came increasing local demands; but the local farmer was tardy in responding to this demand; he was not so thrifty that he regarded his farm investment as a good one; in consequence, the provident foreigner from his days' labor relentlessly saved and so became a farmer. With this gradual supplanting of the New England farmer by the Danes, Germans, Bohemians, and Polanders, came the installation of European thoroughness in agriculture. Intensive and specialized farming rather than the former extensive method was inaugurated as these men became land owners. Farms that had been barely supplying the expenses of living for a Yankee family later formed the basis of permanent bank accounts. The beach ridges were enriched, crops adapted to them were grown; the sandy fields were so treated as to be made more dependable in times of drought; stubborn clay areas were drained and lightened. As the city of Cleveland continued to grow in population, market-gardening in the hands of these foreigners was made very profitable. These new emigrants from old Europe brought with them a training acquired through generations of ancestors

engaged in a struggle for momentary support. This training has made them more valuable as American farmers than as laborers in factories.

In still another direction, we find the lake ridges entering into life relations. For industrial purposes, such as building-blocks and concrete, they furnish a supply of gravel and sand; the extensive deposits of lake and glacial clays have afforded material for brick and tile.

We find a specially interesting physiographic reaction in the influence of the lake-made physiography on railroad construction. In this area, the Cuyahoga was the largest river tributary to these lakes. Into the lake at all stages, the Cuyahoga built an extensive delta and as the lakes dropped from one stage to another, tributary streams have incised this delta which is made up of sand, coarse and fine, and gravels of varying texture. It yields readily to stream work, consequently deep channels were developed. Its lack of stability near the walls of a stream is obvious; for this reason railroads have always hesitated about constructing high bridges.

All railroads centering at Cleveland have either east-west courses bordering the lake, or north-south courses paralleling the Cuyahoga valley. The Lake Shore, as the name implies, belongs to the former class. One other east-west road, however, the Nickel Plate, approaching the city from the east, turns southward near the south side of the delta and descends through the valley of Kingsbury run to the level of the present Cuyahoga river in ascending from which, on the western side, it uses another tributary valley. The Big Four uses this same valley west of the Cuyahoga.

The railroads from the south, that is, the Baltimore & Ohio, Pennsylvania, Wheeling and Lake Erie, with the exception of the Pennsylvania, enter the city through tributary valleys cut in the old delta. The Pennsylvania, however, follows Mill creek to Newburg, then it skirts the Maumee beach for two miles and gradually descends the delta slope to the lake front; the Baltimore & Ohio has a more uniform gradient as it follows the edge of the river channel.

But at the present time, a high level bridge is under construction; this is being built across the Cuyahoga on the delta-top level; it is a part of the recently located "Belt Line" which has become the property of the Lake Shore Railroad Company. From the standpoint of engineering, this is a hazardous venture, a fact which in

the light of the thousands of dollars spent by this company in the last year, much of which has been sunk in the slumping quick sands of this old delta, needs no further comment.

A vital question today in every large American city is speedy transportation for the urban part of its citizens. This fact has led to the construction, in many large centers of population, of subways. For the most part subways in the city of Cleveland would have to be cut through this old delta. Such an undertaking will doubtless present new questions to subway engineers.

This particular part of the southern shore of Lake Erie, if one can clearly interpret the present movement of industry, is destined to be the most thickly populated portion of Ohio. The lake plain here, so far as the city of Cleveland is concerned, even now is too narrow. It is probable that in this assured development many physiographic reactions, new to this region, will arise. This whole composite of conditions, then, is the result of a pre-glacial physiography upon which has been imposed the work of three lake levels, and which is becoming still further complicated by the shore line now in the making.

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PRELIMINARY NOTES ON CINCINNATIAN AND LEXINGTON FOSSILS.[1]

AUG. F. FOERSTE.

The Saluda bed is typically exposed at Madison, Indiana, but the name was taken from Saluda creek, eight miles southwest of Madison, because the latter name was preoccupied. At Madison it consists chiefly of argillaceous limestones forming massive beds, but near the base the rock weathers to thinner layers which northward, in Jefferson and Ripley counties, become more conspicuous and have there, on account of their thin bedding, been called shales. Very fine, microscopic grains of sand are present, which become more abundant southwards, so that in west-central Kentucky the rocks feel gritty between the fingers. The name Saluda was introduced chiefly on lithological grounds, to distinguish the comparatively unfossiliferous fine-grained, argillaceous limestones, forming massive beds at numerous falls, from the underlying thin, blue limestones, interbedded with considerable clay, both richly fossiliferous. As a matter of fact, the Saluda of Indiana and northern Kentucky contains a considerable variety of species, but usually the individual specimens are few, or the specimens do not weather out well and very little effort has been made to collect them excepting at two horizons: at the top, in the Hitz layer, and at the base, immediately above the chief *Columnaria* layer. An effort was made to introduce a paleontological base for the Saluda bed, and the chief *Columnaria* layer, and, in its absence, the massive *Tetradium* layer, was chosen for this purpose. Unfortunately, these coral layers cannot be traced south of Hanover, Indiana, and beyond this locality, only the lithological distinctions can be utilized.

Recently Prof. E. R. Cumings has traced the Saluda northward in Indiana and has shown that it wedges in between the Liberty and Whitewater beds. In Ohio, I have seen the strata thus iden-

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tified at only one locality three miles north of Oxford, on the east side of Four Mile creek, along a branch coming in from the northeast. The characteristic Whitewater fauna is found a quarter of a mile up the branch. Undoubtedly, other localities will be found in the western part of this state, but no corresponding strata are known at present anywhere along the eastern line of outcrop, from Dayton, Ohio, to Concord, Kentucky, and southward.

There are two *Hebertella insculpta* horizons in Ohio. Only the upper one of these horizons was known at the time the name Waynesville bed was introduced, and this upper *Hebertella insculpta* horizon was chosen as the base of the Liberty bed. In reality, there is a greater stratigraphic break immediately above the upper *Hebertella insculpta* horizon, so that the latter should form the top of the Waynesville bed. This upper *Hebertella insculpta* horizon may be traced through Indiana as far southward as Madison. However, within the limits of Jefferson county, the number of specimens at this horizon rapidly becomes less and at Madison only careful search will result in locating the horizon. Recently, Mr. John F. Hammel and the writer located this horizon accurately along the Hanging rock road at Madison, 32 feet below the base of the chief *Columnaria* layer, agreeing essentially with my measurements 5 years ago. *Dinorthis subquadrata* makes its first appearance about 4 feet farther up.

The same species of corals which are found in southern Indiana at the base of the Saluda bed, 32 feet above the top of the Waynesville bed, occur in Kentucky, on the western side of the Cincinnati geanticline, from Jefferson county as far south as the central part of Casey county, but below the lowest horizon containing *Dinorthis subquadrata* and various Liberty fossils. Since this fossiliferous horizon underlies the southern continuation of the Saluda bed it seems evident that the Kentuckian coral horizon here mentioned, which is found at a still lower level, belongs not at the base of the Saluda but at the base of the southern extension of the Liberty bed.

At these coral horizons in Indiana and Ohio the number of specimens of corals often is so great that the name coral reef seems pertinent. For the coral horizon at the base of the Saluda bed the name *Madison coral reef* was introduced and for that at the base of the Liberty bed, the name *Bardstown coral reef.*

Another coral reef of much less importance occurs in the lower

part of the Waynesville bed. In consists chiefly of *Columnaria* with occasional localities in which *Tetradium* is common, and extends from the western edge of Henry county, in Kentucky, as far as the northwestern edge of Nelson county. This may be called the *Fisherville coral reef*, since one of the typical exposures occurs along the railroad west of Fisherville, and another on the road from Fisherville to Jeffersontown.

The most diligent and effective student of the vertical distribution of Richmond fossils undoubtedly has been Dr. George M. Austin of Wilmington, Ohio. To him the writer has been indebted in ways too numerous to mention. Recently it has become evident that the Waynesville bed includes several very distinct divisions to which it would be convenient to assign names. These divisions have been worked out in collaboration with Dr. Austin, and are founded largely on his labors. Three divisions have been adopted in the present paper, in descending order:

Blanchester division.
Clarksville division.
Fort Ancient division.

The Blanchester division includes all between the upper and lower *Hebertella insculpta* horizons and is typically exposed along Stony Hollow, northwest of Clarksville, but is well exposed also a mile west of Blanchester, from which the name was selected. At the lower *Hebertella insculpta* horizon, *Catazyga headi*, and *Dinorthis carleyi-insolens*, occur at various localities. *Strophomena nutans*, *Strophomena neglecta*, and a precursor of *Strophomena vetusta* occur over wide areas and usually in considerable abundance in the middle layers of this division. *Rhynchotrema dentata* occurs in the upper one of two layers in which an abundance of *Rafinesquina* is present, chiefly turned up on edge. *Austinella scovillei* occurs in the corresponding division at Oregonia, Ohio, 5 feet below the upper *Hebertella insculpta* horizon. It is the richest part of the Waynesville bed in the variety of its fauna. East of the Cincinnati geanticline the Blanchester fauna may be traced as far south as Owingsville, Kentucky, although the lower *Hebertella insculpta* layer cannot be traced beyond Adams county, Ohio. On the western side of the geanticline the fauna has been traced as far south as Canaan, Indiana, although *Dinorthis carleyi-insolens* has not been found south of Franklin county.

The Clarksville division is typically exposed along Stony Hollow northwest of Clarksville, Ohio; but excellent exposures occur also over a mile southeast of Fort Ancient and in the Blacksmith Hollow at Oregonia. It extends from the *Orthoceras fosteri* horizon to the lower *Hebertella insculpta* layer. The *Orthoceras fosteri* horizon is exposed along Stony Hollow immediately north of the bridge crossing the little stream forming the hollow. It consists of a layer of clay 5 feet thick, containing *Tetradium*, *Labechia*, various small incrusting bryozoans including *Spatiopora montifera*, as well as a considerable number of *Orthoceras fosteri*. The Clarksville division is notable for introducing a part of the fauna usually considered typical of the Richmond, but not found in the Fort Ancient division of the Waynesville. Within 5 feet of the top of the *Orthoceras fosteri* bed the following species are introduced: *Streptelasma vagans*, *Plectambonites sericea*, *Strophomena planumbona*, *Strophomena sulcata*, and a variety of *Rhynchotrema* resembling *Rhynchotrema perlamellosa*. Within 7 feet of the *Orthoceras fosteri* layer *Leptæna richmondensis* comes in. As a matter of fact, *Streptelasma vagans* is known at the base of the Waynesville bed, at Concord, Kentucky, but this is its only known occurrence at this horizon, and it does not yet characterize the Waynesville bed over any extended territory. The Clarksville fauna may be traced southward as far as Wyoming, in Kentucky, and southern Jefferson county, in Indiana. Farther south, the lithological characteristics of the Waynesville bed change rapidly and the accompanying paleontological features change at the same time, necessarily.

The Fort Ancient division is typically developed along the stream crossed by a north and south road a little over a mile southeast of the Fort. It is characterized by the abundant presence of *Dalmanella jugosa*, with the exclusion of all other brachiopoda and corals considered characteristic of the Richmond. Since *Dalmanella jugosa* has a considerable vertical range in the Arnheim bed in eastern Indiana, and occurs just below the *Dinorthis carleyi* horizon near the middle of the Arnheim bed at numerous localities in Ohio, this absence of characteristic Waynesville brachiopoda becomes more striking. The Fort Ancient division of the Waynesville, moreover, is noteworthy on account of the presence of numerous specimens of certain species of lamellibranchs, including *Anomalodonta gigantea*, *Modiolopsis concen-*

trica, Modiolopsis pholadiformis, Opisthoptera fissicosta, and *Pterinea demissa.* In addition to these, *Rafinesquina loxorhytis* is abundant. Now, as a matter of fact, a very similar assemblage of fossils occurs in the upper part of the Arnheim bed in the eastern part of Indiana and suggests the idea that the Fort Ancient division of the Waynesville bed belongs with the upper part of the Arnheim, rather than with the Clarksville and Blanchester divisions of the Waynesville bed. The first specimens of *Bythopora meeki* were noticed 28 feet above the base of the Fort Ancient division, but it may occur lower. The Richmond form of *Platystrophia laticosta* comes in 7 feet below the base of the *Orthoceras fosteri* zone.

The lower part of the Garrard sandstone of central Kentucky consists of massive argillaceous and more or less siliceous fine-grained limestones, with few fossils, differing conspicuously from the thinner bedded argillaceous limestones, interbedded with considerable clay, which overlie it and form most of the upper part of this Garrard sandstone. To the lower, massive part the name Paint Lick bed was applied. The overlying part was correlated with the Mount Hope bed on account of the presence of *Strophomena maysvillensis*, and other fossils which northward begin their range with the Mount Hope bed. The lower or massive part, called the Paint Lick bed, was correlated with the upper Eden, because it was believed that it could be traced stratigraphically northward into beds containing *Dekayella ulrichi* and other characteristic Eden fossils.

The underlying Eden beds in central Kentucky, were included in the Million bed. This bed includes the southern continuation of the Southgate bed and, at its base, a peculiar fauna including: *Climacograptus typicalis, Ectenocrinus simplex, Lichenocrinus crateriformis, Heterotrypa foerstei, Crepipora venusta, Escharopra falciformis, Arthropora cleavelandi, Monotrypa subglobosa, Constellaria florida-prominens, Dalmanella emacerata, Dalmanella multisecta,* a species of *Hebertella,* a species of *Platystrophia, Plectorthis (Eridorthis) nicklesi, Plectorthis (Eridorthis) rogersensis, Clitambonites diversus-rogersensis, Plectambonites sericea, Strophomena hallie,* a *Cyclonema* with a rather low spire, *Fusispira sulcata, Cyrtolites ornatus, Byssonychia vera, Primitia centralis, Ceratopsis chambersi, Trinucleus concentricus,* a species of *Ceraurus,* one of *Acidaspis* belonging to the *Acidaspis anchoralis* group, and a species

of *Calymmene* which differs from that usually identified as *Calymmene callicephala* by its smaller size and by the presence of numerous granules, larger and more conspicuous than in the latter species. The anterior border of the cephalon appears less strongly elevated anterior to the glabella. For this form, the name *Calymmene callicephala-granulosa* is suggested here. The typical specimens are found in the lower part of the Eden formation, at Cincinnati, Ohio. My chief object in referring to this horizon at Rogers Gap at the present time is to call attention to the fact that this fauna is now known to have a wide distribution in central Kentucky and evidences of its existence are being found farther northward. The exposures as far north as Sadieville are practically continuous. The same fauna occurs also north of Ford, near Hutchison, at the Lower Blue Lick Springs in the northern edge of Nicholas county, and northward. Recently, *Plectorthis (Eridorthis) nicklesi*, and *Plectorthis (Eridorthis) rogersensis* have been found, in strata formerly included in the Lower Eden, at various localities between Cincinnati and Foster. Among these localities are the quarries at Ivor, the lower part of Nine-mile creek, and the exposures below Fort Thomas.

Recent observations by E. O. Ulrich indicate that along the Ohio river the lower part of the strata formerly included in the Lower Eden include a much larger Fulton element than formerly suspected, and that the typical Economy fauna begins higher up. This lends additional interest to the Rogers Gap fauna, whose peculiarities were recognized in part even from the earliest observations. The exact relationship between the Rogers Gap fauna and that of the extended Fulton section, has not been worked out; however, it is known that both species of *Eridorthis* occur in this extended Fulton.

Sections occupying a similar position at the base of the Eden formation, and which apparently should be distinguished from the Economy bed, occur at Sparta, and west of Drennan Springs, Kentucky.

The term Nicholas bed was intended to include only the upper part of the Cynthiana formation, consisting of rather coarse-grained limestone with relatively few fossils. This part is typically exposed between Pleasant Valley and Millersburg. Exposures occur at least as far south as Winchester, and apparently also in the western part of Madison county. Toward the north and northwest the limestones become more argillaceous, fine grained layers are more frequent, and fossils are more abundant.

The underlying part, characterized by the presence of a considerable fauna, including *Orthorhynchula linneyi*, *Hebertella maria-parksensis*, *Eridotrypa briareus*, *Constellaria emaciata*, *Homotrypella norwoodi*, is called the Greendale bed, this designation having been given at an earlier date to the southern extension of this bed in Fayette county, Kentucky.

The northern extension of this fauna along the Ohio river, east of Cincinnati, especially the localities at Point Pleasant, Ivor, Carnestown and Foster, have been known a considerable time, and a very characteristic fauna has been collected at Ivor, Ky. At the latter locality, *Orthorhynchula linneyi* occurs, occasionally, at the level of the railroad. At Carnestown, a single specimen of *Orthorhynchula linneyi* was found 10 feet above the level of the railroad, at the top of a contorted layer of fine-grained limestone. This probably is at about the same horizon as the contorted layer of limestone which formerly was exposed just above railroad level at the quarry a quarter of a mile east of Ivor.

The interval from this *Orthorhynchula linneyi* horizon, at Ivor and Carnestown, Kentucky, down to the *Callopora multitabulata* horizon is approximately 50 feet. It is this interval which forms the lowest fifty feet in the Ordovician section at Point Pleasant. It is this interval which includes the Point Pleasant beds of Professor Orton. At the time Professor Orton was writing his report, on the Geology of the Cincinnati Group, in volume I of the Ohio Geological Survey, rock was quarried at river level in the western edge of Point Pleasant and sent by river barges to Cincinnati. These were the lowest rocks exposed in the state and must have formed the base of his 50 foot section. The quarrying operations were continued until most of the rock which could be easily removed had been quarried out and the overload was too great to make further work at these lower levels profitable. Even before the lower quarries at river level were abandoned those above the level of the pike were opened up, but on that account it must not be assumed that Professor Orton's measurement of 50 feet began with the road level in place of the river level.

Moreover, the base of the shaly section at Point Pleasant, Ohio, is located about 113 feet above the Ohio river. This shaly section undoubtedly formed the base of the Eden shales in Professor Orton's section. If from the underlying part the upper 50 feet were subtracted, as probably equivalent to the River quarry beds

at Cincinnati, the underlying part would have been about 50 feet thick.

Time has dealt unkindly with Professor Orton's type section of the Point Pleasant beds. Formerly the stream passing between the quarries above the road level, a half mile west of Point Pleasant, exposed a very fair section down to the river level. Then a larger culvert was put in and the exposures gradually became covered. At the time this section was investigated by Professor Joseph F. James, (On the Age of the Point Pleasant beds)[1] there was a very fair exposure of the strata from 11 feet above the river level to 22 feet above the river level. Between 22 and 34 feet, there was enough exposed to give some idea of the material forming the section. The beds nearer river level, some of which formerly had been quarried, but only at very low water, had been covered up and the débris at the culvert, the wash of the stream having been checked, covered up the upper part of the section. Professor James unquestionably was correct in assigning the lower 50 feet of the Point Pleasant section, from the level of the culvert down to river level, to the Point Pleasant beds. The rocks exposed above the road level must have been interpreted as River Quarry beds by Professor Orton.

It remains now only to determine what the Point Pleasant beds of Orton are in terms of sections described elsewhere. The only statement that can be made at present is that *Callopora multitabulata*, a species of *Prasopora*, probably *Prasopora simulatrix*, *Zygospira recurvirostra*, *Dalmanella bassleri*, *Strophomena vicina*, a species of *Platystrophia*, and *Plectambonites sericea* occur immediately beneath the Point Pleasant section, at Carnestown, Ky. It is possible that *Callopora multitabulata* formerly may have occurred even at very low water level at Point Pleasant itself, since it occurs a little above river level at the landing at Ivor. At present I know of this combination of fossils only in the Paris bed. *Strophomena vicina* has not been found in the Greendale or Wilmore beds, although occurring in the Paris bed and also at the Flanagan horizon. *Callopora multitabulata* is known both from the Paris bed and from the Wilmore bed but not from the Greendale bed. This is true also of *Prasopora simulatrix*. *Platystrophia* is known both from the Greendale and the Paris beds, and there is no reason

[1] Journal of the Cincinnati Society of Natural History, volume XIV, 1891, p. 93.

why it should not occur in the Wilmore bed, but I have never seen it from that horizon.

For the convenience of those who desire a ready abstract of the classification here in use, the following table is added.

Series.	*Formations.*	*Beds.*
Cincinnatian	Richmond	Elkhorn
		Whitewater
		Saluda
		Liberty
		Waynesville
		Blanchester division
		Clarksville division
		Fort Ancient division
		Arnheim
	Maysville	Mount Auburn
		Corryville
		Bellevue
		Fairmount
		Mount Hope
	Eden	McMicken or Paint Lick
		Southgate
		Economy
	Utica	Fulton
	Cynthiana	Nicholas
		Greendale
		Perryville
Upper Mohawkian	Lexington	Paris
		Wilmore
		Logana
		Curdsville

In this classification the Rogers gap beds appear to belong between the typical Economy and the typical Fulton beds, but require further study before their exact limits are defined. A similar statement might be made also of the Point Pleasant beds, which belong below the *Orthorhynchula* horizon along the Ohio river which is definitely recognized as Greendale, and which probably belong above the Paris bed, but which require further study.

Beatricea undulata, Billings.

(*Plate VIII, Fig. 3.*)

Erect columnar growths with longitudinal rounded ridges separated by broad shallow grooves. The ridges and grooves are not necessarily continuous along the entire length of the stem but neighboring ridges may gradually disappear or run together and be replaced by others farther up the same stem. There frequently is a slight spiral twist to these grooves, which occasionally becomes more pronounced. The specimens found in Kentucky and Indiana usually do not exceed 60 millimeters in diameter but larger specimens are found in Canada.

Geological position. In the lower part of the southern extension of the Liberty bed, in Bullitt, Nelson, and Marion counties, Kentucky. The specimens figured were obtained at Bardstown, Kentucky. The most southern specimens were found 2 miles northeast of Liberty, in Casey county, associated with *Columnaria vacua*, *Tetradium minus*, and *Labechia ohioensis*, at the base of the Liberty bed. It occurs at the corresponding horizon north of Ophelia, 4 miles north of Richmond, in Madison county.

In Indiana, good specimens have been found a short distance above the chief *Columnaria* layer, near the base of the Saluda bed, along the Hanging rock road, at Madison.

In some specimens of *Beatricea* the longitudinal ridges are much less distinctly defined than in the specimen here figured. Sometimes these ridges are rather indefinite in direction and irregular in elevation, becoming nearly obsolete on some parts of the body. A specimen of this type, 60 millimeters in diameter, was found in the upper part of the Liberty bed north of Canaan, Indiana. Much smaller specimens of the same general type occur 14 and 29 feet below the Brassfield or Clinton bed, in the Elkhorn bed, along Elkhorn creek, south of Richmond, Indiana. It is the extreme forms of this variety, without any indication of ridges, which here are figured as *Beatricea undulata-cylindrica*.

Beatricea undulata-cylindrica, var. nov.

(*Plate IX, Fig. 7.*)

In typical specimens of *Beatricea undulata* the vertical ridges and intervening grooves are at least sufficiently distinct to be

detected readily. Occasional specimens occur destitute of both ridges and nodes. These may be only extreme variants of *Beatricea undulata*, and here are figured as *Beatricea undulatacylindrica*.

Geological position. Four miles north of Richmond, Kentucky, half a mile north of Ophelia, in strata corresponding to the southern extension of the Liberty bed as exposed in Boyle, Casey, Marion, Washington, Nelson, and Bullitt counties. At Ophelia this smooth form of *Beatricea* is associated with *Beatricea undulata*, *Beatricea nodulosa*, *Labechia ohioensis*, *Columnaria alveolata*, *Calapœcia cribriformis*, *Streptelasmavagans*, *Platystrophia acutilirata*, and other fossils. Similar specimens have been found at the same horizon immediately west of Fredericktown, in Nelson county, and in the northeastern part of Raywick, in Marion county, Kentucky; also in the Elkhorn bed, along Elkhorn creek, south of Richmond, Indiana.

Beatricea nodulifera, sp. nov.

(*Plate VII, Fig. 13; Plate VIII, Fig. 5.*)

Cylindrical stems with nodes more or less irregular in arrangement, but tending toward arrangement in vertical rows with a slight spiral twist around the stem. In specimens in which this arrangement in vertical rows is most pronounced, some of the nodes are connected sufficiently to suggest vertical ridges separated by more or less irregular furrows. The lateral distance between these rows or ridges varies from 5 to 7 millimeters. In other specimens, the arrangement is more irregular. Specimens 50 millimeters in diameter have been collected, and the species is known to attain a larger size. The stems were several feet in length and grew in a vertical position, tapering slowly toward the top.

Geological position. The type specimens were obtained five feet below the base of the Devonian limestone, at a small falls a quarter of a mile south of the Sulphur Spring, three miles south east of Lebanon, Kentucky. Here *Columnaria* and *Tetradium* occur within three feet of the base of the Devonian limestone, and *Beatricea nodulifera*, *Beatricea undulata*, *Heterospongia subramosa*, and *Columnaria* occur two feet lower. This horizon is regarded as the base of the Liberty bed. Specimens have been found at the same horizon at Bardstown, Ky.

Beatricea nodulosa was described from the Ordovician at Wreck Point, Salmon River, and Battery Cliff, on Anticosti Island. The types appear to have been lost. A specimen from Battery Cliff, preserved in the Museum of the Geological Survey of Canada, owes its nodose character to a parasitic growth of *Labechia*. Judging from the specimens of *Beatricea* preserved in the Museum of the Canadian Survey, the nodes of *Beatricea nodulifera* are smaller and closer together. It will be necessary to collect specimens from the type localities in Anticosti in order to determine definitely how wide a range of variation is to be assigned to *Beatricea nodulosa*. For the present, the specimens here described as *Beatricea nodulifera* are regarded as distinct.

A specimen of *Beatricea*, found at Connersville, Indiana, was identified as *Beatricea nodulosa* by A. C. Benedict.

Beatricea nodulifera-intermedia, var. nov.

Plate VIII, Fig. 4, A, B. C.

Among the various aberrant forms of *Beatricea* found in Kentucky is one in which the nodes are considerably elongated, forming short ridges. The upper end of one of these short ridges frequently terminates slightly to the right or left of the lower end of one of the short ridges located farther up the stem, thus resulting in a vertical serial arrangement similar to that of *Beatricea nodulifera*. It is probably one of the extreme variants of that species.

Geological position. Near the base of the southern extension of the Liberty bed, in Marion county, Kentucky.

Brachiospongia lævis, sp. nov.

Plate VIII, Fig. 2.

In the specimen here figured the body has a horizontal diameter of about 75 millimeters, and a vertical diameter of 30 millimeters. However, since only one side of the body is well preserved, its original vertical diameter is unknown. The preserved sid is moderately convex toward the middle. It rested upon clay, and was partially imbedded at the time of discovery. It is assumed to have been the lower side of the body. If the upper side was occupied by a large osculum, no trace of the latter is preserved.

There are seven arms, approximately cylindrical at their bases horizontally flattened near the ends, but this flattening may have been due to crushing. There is no evidence of geniculate bending of the arms as in *Brachiospongia digitata*. The upper surface of the specimen, both in the region of the body and arms, contains numerous fragments of shells indicating either that the specimen was hollow, or that it consists only of an impression of the lower side of the original animal. The first view is favored at present.

Geological position. In the southern extension of the Mount Hope bed, about a mile north of Paint Lick, in Madison county, Kentucky At this point a road turns off westward from the Richmond pike and follows the northern side of a small stream entering Paint Lick creek. About 80 feet below the top of the section exposed along this road, *Strophomena maysvillensis* and *Constellaria florida* are very abundant. Below this is a series of argillaceous limestones interbedded with clay, about 30 feet thick, referred to the Mount Hope bed. This is the upper part of the Garrard sandstone of Marius R. Campbell. *Brachiospongia lævis* occurs two and a half feet above the base. The lower, massive part of the Garrard sandstone, regarded as the equivalent of the upper part of the Eden, equals at least 66 feet at this locality. To this lower part the name *Paint Lick bed* has been given.

In the Monograph on the *Brachiospongidæ*, Memoirs of Peabody Museum, volume 2, part 1, published in 1889, Prof. Charles E. Beecher published the following description of a specimen found in Spencer county, Kentucky:

A specimen of *Brachiospongia* found by W. M. Linney in the northern part of Spencer county, Kentucky, in strata of the Middle Hudson series, offers some points of difference with those from Franklin county. It is preserved in mudstone, and the parenchym of the sponge has been replaced by calcite. The specimen measures 235 millimeters in diameter, and has eight arms, which are constricted at their origin, directed outwards and downwards at an angle of forty-five degrees, and are not geniculated as in typical *Brachiospongia digitata*. The osculum is suborbicular, and the neck is campanulate below. The cup, or body, of the sponge is comparatively small. The base is flat, and without the initial projection usually present. Were it not for the great range of variation shown in the specimens from Franklin

county, it would seem that this form represented a distinct species. The differences are probably due to changed physical conditions.

The Middle Hudson strata of Linney are the stratigraphical equivalent of the Garrard sandstone of Campbell. The mudstone is an argillaceous limestone. The stratigraphical position of Linney's specimen and that here described as *Brachiospongia lævis* undoubtedly is the same. There is very little doubt as to the specific equivalency of the two specimens. From this it follows that *Brachiospongia lævis* has a suborbicular osculum, campanulate below. The number of arms probably varies as in *Brachiospongia digitata*. The absence of geniculation probably is a specific characteristic. The arms of the specimen from Madison county are much longer, but this may be due to better preservation.

Dystactospongia madisonensis, sp. nov.

(*Plate IX, Figs. 1, 5.*)

Sponge massive, irregularly lobate; the lobes in one specimen attain a length of 100 or more millimeters, with a diameter of about 40 millimeters. The surface of these lobes may be comparatively even or slightly nodose. Sometimes one of the lobes is traversed vertically by a broad groove, probably a case of incipient lobation. In the central parts of the sponge, the fibers appear to anastomose so as to produce an irregular net-work, but toward the surface a series of vertical passages results. These passages vary from 4 to 7 millimeters in length, are perpendicular to the surface, are about half a millimeter in diameter, and are separated by cœnenchym having about the same thickness. The openings at the surface are irregular, the larger ones frequently attaining a width of one millimeter, between which the smaller openings are interspersed. In the specimen from the vicinity of Versailles, oscula between 1.5 and 2 millimeters in diameter, and from 7 to 14 millimeters apart, are present. In other specimens, oscula were not noticed. In the specimen from Madison, this coarser sponge structure appears to be covered by a thin film without apertures but with numerous irregular elevations as in some specimens referred to *Labechia*. For the present this is regarded as a parasitic stromatoporoid growth.

Geological position. Lower part of the Saluda bed. Along

the Hanging Rock road, at Madison, Indiana, a specimen was found about 7 feet above the chief *Columnaria* bed, in sandy layers, associated with *Rhynchotrema capax*, *Strophomena sulcata* and *Streptelasma*. Two specimens were found a little over two miles south of Versailles, Indiana, opposite the home of Porter Harper, 65 feet below the base of the Clinton, immediately below the *Tetradium* horizon, in strata regarded as forming the base of the Saluda bed. Several specimens were found also a mile and a half northeast of Osgood, Indiana, in the lower part of the *Tetradium minus* bed, associated with numerous specimens of *Columnaria alveolata*, some of *Calapœcia cribriformis*, and the same forms of *Byssonychia* as those found in the *Tetradium* layer opposite the home of Porter Harper.

Heterospongia, sp.

(*Plate IX, Fig. 2.*)

The distinguishing features of *Heterospongia knotti* are the presence of oscula, scattered over the surface at intervals of 8 to 20 millimeters, and the relatively small apertures between the meshes of sponge fibers, about 6 to 8 in a length of 5 millimeters. These apertures tend to be rounded instead of roughly angular. In other respects this species closely resembles *Heterospongia subramosa*, a much more common species.

The specimen here figured appears to have poor indications of oscula and appears more closely related to *Heterospongia knotti* than to *Heterospongia subramosa*. It was found southeast of Lebanon, Kentucky. The types of *Heterospongia knotti* were found near Lebanon, Kentucky, but their exact horizon has not been determined. *Heterospongia* is found here both in the Liberty bed and in the upper part of the Maysville formation, in strata belonging below the *Dinorthis carleyi* horizon. All of the specimen found in situ belonged to the species *Heterospongia subramosa*.

Pasceolus darwini, Miller.

(*Plate VIII, Fig. 1, A, B.*)

Body spherical, consisting of a covering of polygonal plates, chiefly hexagonal, surrounding a body cavity at present filled with

argillaceous rock within which no structure has been discovered. The plates usually are not preserved, so that the fossil usually consists of a structureless globular mass with polygonal concave depressions locating the former position of the plates. The surface of the plates frequently is marked by radiating grooves extending from the central part toward the angles, near which they become indistinct. The fossils usually have a depressed globular form. This evidently is due to sagging, the fossil being preserved in a clayey matrix. The lower side frequently is indented by a broad shallow depression, which also may be due to pressure, but which for the present is regarded as diagnostic.

Geological position. At the base of the Bellevue bed, along the railroad two miles southeast of Maysville, Kentucky, in a layer of clay two feet thick, and in the immediately overlying limestone.

Specimens identified as *Pasceolus darwini* occur in the Valley school house railroad cut, between a mile and a half and two miles south of Lebanon, Ohio.

Specimens of *Pasceolus* retaining only the cavities left by the plates and resembling *Pasceolus darwini* occur a mile and a half northeast of Modest, Ohio, along a road crossing the direct road to Edenton, a short distance beyond Stone Lick creek, immediately above the *Platystrophia ponderosa* horizon near the middle of the Arnheim bed.

Astylospongia tumidus, James, appears to be identical with *Pasceolus darwini*. One of the best preserved specimens among the series of types preserved in the James collection in the Walker Museum at Chicago University shows a rather deep depression on the side usually regarded as the base. Several of these specimens show distinctly the stellate grooves on the surface of the polygonal plates. These specimens are labelled as coming from a level of 350 feet above low water in the Ohio river. Miller cites *Pasceolus darwini* from the hills back of Cincinnati at an elevation of about 400 feet above low water. From this it is evident that *Pasceolus* occurs at Cincinnati either in the Bellevue horizon or in the immediately underlying or overlying strata.

Pasceolus darwini agrees with *Pasceolus intermedius* in size of the body and in the size of the polygonal plates. The types of *Pasceolus intermedius*, Billings, are preserved in the Museum of the Geological Survey of Canada. Only the depressions left by the plates remain. The specimens are globular and vary from

25 to 28 millimeters in width. No depression was noticed on the basal surface. Four hexagonal plates occur in a width of 7 millimeters. The depressions left by the plates are concave as in *Pasceolus darwini*. The association of *Pasceolus intermedius* with a Silurian rather than Ordovician fauna suggests that when this species is better known it will prove distinct from *Pasceolus darwini*.

Streptelasma vagans, nom. nov.

(*Plate XI, Figs. 1, A, B, C.*)

The species of *Streptelasma* from the Richmond group of Ohio, Indiana, and Kentucky, long known as *Streptelasma corniculum*, has been referred more recently to *Streptelasma rusticum*, from the Hudson River group of Snake Island, in Lake St. John, in the province of Quebec, in Canada. Recently, L. M. Lambe has figured a specimen of *Streptelasma rusticum*, and, judging from his figures, this species is much more nearly cylindrical toward the top, and relatively more narrow than is true of the species characteristic of the Richmond of the region affected by the Cincinnati geanticline. *Streptelasma canadensis*, Billings, from the Hudson River group on Drummond Island, in Lake Huron, appears to have the inner edges of the septa more nearly vertical, producing a wider calyx, with a flatter bottom.

In the specimens from the Whitewater beds, at Dayton, Ohio, the corals more nearly resemble *Streptelasma canadensis* in form, but are less wide at the top. The number of primary septa is about 60 to 65. The secondary septa, approximately equal in number, do not extend more than one millimeter from the thickened walls of thc corals; frequently they appear not much more conspicuous than prominent striations. The calyx is conspicuously narrower at the base than near the top. In a specimen 25 millimeters wide at the top, the twisted central area at the base of the calyx equals about 8 millimeters in width, and the width of the base of the calyx, limited by the inner edges of the septa, does not exceed 10 millimeters. The free edges of the septa are not denticulated. While this species undoubtedly is closely related to *Streptelasma canadensis*, it is not regarded as identical.

Geological position. The type specimens are from the Whitewater bed at Dayton, Ohio. At this horizon they are abundant

in Ohio and Indiana. In the Liberty bed similar forms are common in Ohio and Indiana, and at the more northern localities in Kentucky. Southward, along the eastern side of the Cincinnati geanticline, at Wyoming, Owingsville, Howards Mill, it is confined to the base of the Liberty. The specimens found at the Merritt ferry, at the mouth of Red river, near College Hill, and Cobb Ferry, in Madison county, probably belong to about the same horizon. They occur at the base of the Liberty at Ophelia, north of Richmond. They occur in the Liberty bed also on the western side of the Cincinnati geanticline, as far south as Marion county. This may be the horizon also of the specimens found on Fishing creek, east of Somerset, in Pulaski county. In the upper or Blanchester division of the Waynesville bed *Streptelasma vagans* is common in Ohio, Indiana and northern Kentucky, although associated with *Streptelasma dispandum* which locally almost replaces the former species. Occasional specimens occur below the chief *Columnaria* layer, which forms the base of the Liberty bed, also in the vicinity of Bardstown, Kentucky. They are quite abundant at several horizons in the lower part of the middle or Clarksville division of the Waynesville bed in Clinton and neighboring counties, in Ohio. At Concord, Kentucky, they occur both 5 feet above and 5 feet below the *Strophomena concordensis* layer which there forms the base of the Waynesville bed.

Streptelasma insolitum, sp. nov.

(*Plate X, Fig. 3.*)

A small and relatively slender form of *Streptelasma* occurs occasionally in the Whitewater strata, along their southern edge of exposure, in Decatur, Jennings, and Ripley counties, in Indiana. The type specimen, from the Whitewater bed, a mile and a half southeast of Westport, on the east side of Painter creek, does not preserve the sides of the calyx, but the septæ leave a central area of only about 4 millimeters for the base of the calyx, the diameter of the coral at this level being 18 millimeters. A similar specimen was found at the same horizon about two and a quarter miles south of Versailles, opposite the home of Porter Harper.

Streptelasma dispandum, sp. nov.

(*Plate IX, Figs. 4, A, B.*)

In the Upper or Blanchester division of the Waynesville bed, along the creek southeast of the railroad station at Moores Hill, Indiana, a large robust form of *Streptelasma* occurs which differs from *Streptelasma vagans* chiefly in its more rapid rate of expansion. This is conspicuous especially in young specimens. When fully mature some of the largest specimens resemble *Streptelasma canadensis* in form much more closely than is true in case of typical specimens of *Streptelasma vagans,* from the Whitewater beds.

Geological position. Abundant in the Blanchester division of the Waynesville bed at Moores Hill, Indiana. Also, at the same horizon on the bluff east of Laughery creek, nearly a mile northeast of Versailles; along the creek, half a mile south of Olean; and along the creek, north of Canaan; all in Indiana. Specimens of the same type have been found at corresponding horizons in Ohio, but no attempt has been made to work out their geographical distribution.

Streptelasma divaricans, Nicholson.

(*Plate X, Figs. 4, A, B, C, D, E.*)

Streptelasma divaricans appears to be a small, sessile species, attached to shells or other objects. Usually two or three specimens are attached to the same shell, at about the same point, but sometimes more than a dozen may be found in the same cluster. The individual corals are inverted conical in shape. Where growing in clusters, the sides usually are more or less adnate, and may be deformed by pressure. The area of attachment usually is more or less oblique to the base, preserving the conical form of the coral on its free side. Occasionally a radicular expansion of the edges of the area of attachment is noticed. Specimens may be found in which the corallites are free at the top, but the presence of lateral gemmation has not been demonstrated in any specimens at hand.

Geological position. In the original description of this species one specimen is described as attached to the brachial valve of *Rhynchotrema dentata.* Although *Rhynchotrema dentata* occurs at

three horizons, in the upper part of the Whitewater bed, in the upper part of the Waynesville bed, and near the middle of the Arnheim bed, it is probable that the type of *Streptelasma divaricans* came from the Whitewater. *Streptelasma divaricans* is very common in the Whitewater bed in Ohio and Indiana, and occurs in Ohio, Indiana, and Kentucky in the Liberty bed, but *Rhynchotrema dentata* is very rare in the Liberty bed. A small sessile form of *Streptelasma* occurs in the upper or Blanchester division of the Waynesille bed at Versailles, Indiana, but it is rare at this horizon. In the Liberty bed *Streptelasma divaricans* it is found as far south as Bardstown, Kentucky. The most southern locality on the eastern side of the Cincinnati geanticline is at the Hornback curve, two miles west of Indian Fields, in Clark county. The horizon here appears to be a considerable distance above the base of the Liberty bed but the presence of the Whitewater bed has not been demonstrated as yet.

In the lower part of the Whitewater bed, a mile and a half southeast of Westport, Indiana, on the east side of Painter creek, a specimen of *Rafinesquina* was found to which 3 separate specimens of *Streptelasma divaricans* were attached, in each case so that all of one side was adnate to the shell. This appears to be only an extreme case of the oblique attachment often seen in specimens unequivocally identical with *Streptelasma divaricans*.

Streptelasma divaricans-angustatum, var. nov.

(*Plate IX, Fig. 6, A, B.*)

Several specimens of *Streptelasma divaricans* have been found in the Whitewater bed at Osgood, Indiana, which differ from the more typical examples of that species in having the sides less divergent. The form of the individual corals, therefore, is more nearly cylindrical. It appears to be a rare variant.

Protarea richmondensis, Fœrste.

(*Plate VII, Fig. 8.*)

The type of this species, here figured, is characterized by the presence of 12 distinct septa. It was found in the Whitewater beds, at Tate's hill, east of Dayton, Ohio. This form occurs at the same horizon at numerous localities in Ohio and Indiana,

In the Liberty beds it is common from Ohio and Indiana as far south as central Kentucky. It makes its first appearance in the upper part of the Middle or Clarksville division of the Waynesville bed, in Clinton and Warren counties, Ohio, and occurs also in the Upper or Blanchester division.

Typical specimens of *Protarea richmondensis* are associated with other specimens in which the septa are much less distinct. They appear to be replaced by papillæ, those along the margins of the calyces being larger, those at the base being smaller. At times these papillate specimens resemble growths of *Protarea richmondensis* covered by a thin film of the so-called *Stomatopora* or *Labechia papillata*. However, if this were the case, the so-called *Labechia papillata* should be common also on other fossils at the same localities, which is not the case. This papillate form of *Protarea* is illustrated by figures 9A and 9B, on plate V, in volume XIV of this Bulletin, and also on Plate X, figs. 2A, and 2B accompanying the present article.

The most southern locality at which *Protarea richmondensis* has been found is at Raywick, in Marion county. On the eastern side of the Cincinnati geanticline it has been found as far south as directly east of Wyoming, in the southwestern part of Fleming county. At both localities the horizon was the Liberty bed.

Protarea ? verneuili, Edwards and Haime.

(*Monographie des polypiers fossiles des Terrains Palæozoiques, 1851, p. 209.*)

Polypier en masse elevee, convexe; calices polygonaux, peu inegaux, separes par des murailles assez minces et presentant a leurs angles de petites colonnes greles: une vingtaine de cloisons peu inegales, assez minces; largeur des calices 3 millimetres.

Silurien inferieur. Alexanderville, Ohio.

Collection de Verneuil.

Unfortunately the type has been lost. This species is not a *Protarea*, that genus not possessing 20 septa. It scarcely could be a *Columnaria* since that genus was familar to Edwards and Haime and does not resemble *Protarea*. Moreover, the statement that the septa differed little in size and that the cell walls present at their angles some small slender columns scarcely agrees with *Columnaria*. As a matter of fact, however, some specimens of *Calapœcia* have a superficial resemblance to *Protarea*. The

septal lines of both are distinct at the mouth of the calices, and extend only a short distance from the walls, leaving circular spaces at the center, and both show traces of denticulate margins along the septa. The fact that the calices are described as polygonal need not disconcert the student since even Nicholson described *Calapœcia cribriformis* as having the corallites for the most part hexagonal or polygonal. Specimens of *Calapœcia* occasionally occur with calices fully 3 millimeters in diameter. Moreover, the base of the Liberty bed occurs at several localities within two or three miles of Alexanderville, and *Calapœcia* has been found at this horizon. It is my belief that if the type of *Protarea verneuilli* ever should be found it would turn out to be a *Calapœcia;* either that, or it is not an Ordovician species at all.

Calapœcia cribriformis, Nicholson.

(*Plate XI, Fig. 4.*)

Calapœcia cribriformis has cylindrical corallites which retain their cylindrical form owing to the fact that the walls of adjacent corallites are not in continuous contact as in genera of corals having polygonal corallites. The walls are penetrated by numerous mural pores arranged more or less in horizontal rows. The septal lines are distinct. In well preserved specimens their free edges are denticulate. The tabulæ usually are not well preserved or may be absent, but probably were present in all cases originally, since they are abundant, alternating with the horizontal rows of mural pores, in the various species of *Calapœcia* described by Billings.

Calapœcia cribriformis appears to be identical with *Calapœcia huronensis,* Billings, and the former name probably should be dropped, as acknowledged by Nicholson himself in later years.

Geological position. Calapœcia cribriformis is common at some localities west of the Cincinnati geanticline in the lower part of the Liberty bed, from Henry county as far south as Marion county, Kentucky. It occurs at the same horizon at Wyoming, Cobb Ferry and 4 miles north of Richmond, in Kentucky. In the lower part of the Saluda bed it occurs from Madison, Indiana, as far north as Osgood. Stray specimens occur in Indiana as far north as Richmond, and are known in Ohio at various localities in Clinton and adjacent counties. Near Clarksville, Ohio, speci-

mens have been found near the base of the Liberty bed. John Misener found two specimens at Richmond, Indiana; one in the Liberty bed; and the other in the upper part of the Whitewater bed.

Tetradium minus, Safford.

(*Plate X, Figs. 1, A. B.*)

This species is recognized readily by its small quadrangular corallites, breaking apart lengthwise so as to show an apparently fibrous structure. On close examination the presence of four septa, one attached near the middle line of each of the four walls, may be noticed. Additional septa may exist but require the use of a magnifier for detection.

Geological position. A species of *Tetradium* associated with the stromatoporoid usually called *Labechia ohioensis* occurs in the Fairmount bed on the Cumberland river, in Russell county, 2 miles east of Rowena, Kentucky. Small specimens are found 20 feet above river level, and larger specimens are found 35 feet above the river. The intervening rock contains *Orthorhynchula linneyi*. *Tetradium* and *Labechia* may be traced up the river as far as the exposures a quarter of a mile below Belk island. *Tetradium minus* occurs with the same association of fossils also in Maury county, Tennessee.

In the lower part of the Waynesville bed it occurs at Owingsville and Wyoming east of the Cincinnati geanticline and north of Mount Washington and west of Fisherville west of the geanticline. all in Kentucky. In Clinton county, Ohio, it makes its appearance in the *Orthoceras fosteri* horizon bed, at the base of the middle or Clarksville division of the Waynesville bed. East of Pendleton, Kentucky, and at the mouth of Bull creek, Indiana, it is common at a horizon which appears to be the upper part of the Waynesville bed. At the base of the Liberty bed it is quite abundant at many localities west of the Cincinnati geanticline, in Kentucky. The most southern localities are in Marion county, Kentucky. Occasional specimens are found in Indiana. On the eastern side of the geanticline it is much less common, but occasional specimens are found in the base of the Liberty bed as far south as Concord, Kentucky. It is possible that the specimens found at the Merritt ferry opposite the mouth of Red river, and several miles west of

Crab Orchard, east of Cedar creek, belong to the same horizon. It is an abundant fossil at the base of the Saluda bed in Jefferson and Ripley counties, in Indiana. At the top of the Saluda bed it occurs at numerous localities in Jefferson county, Indiana. In the Elkhorn bed it occurs both in Indiana and Ohio.

Columnaria alveolata, Goldfuss.

(*Plate XI, Fig. 3.*)

This species is readily distinguished in the region of the Cincinnati geanticline by its conspicuous septa, half of which almost or quite reach the center of the corallites.

Geological position. In the lower part of the Liberty bed this species may be traced from Jefferson county to the middle of Casey county, Kentucky. It occurs at the same horizon four miles north of Richmond and between Stanford and Crab Orchard. Large specimens occur half way between Peewee valley and Brownsboro, presumably at the same level. From Hanover and Madison, Indiana, as far north as the exposures two miles northeast of Osgood, they occur at the base of the Saluda bed, in some localities abundant, at others very rare. The specimens found by John Misener near the base of the exposures below Richmond, Indiana, probably came from the Liberty horizon. From the western part of Henry county, in Kentucky, to the northwestern edge of Nelson county, specimens also identified as *Columnaria alveolata* are common locally at one horizon in the lower part of the Waynesville bed. At Concord, Kentucky, specimens of *Columnaria alveolata* occurred not only at the base of the Liberty bed but one specimen was found also near the base of the Waynesville bed, associated with *Streptelasma vagans*, 5 feet above the *Strophomena concordensis* horizon. At Clifton, Tennessee, several specimens occurred in the Arnheim bed. *Columnaria alveolata* occurs near the base of the Liberty bed in Stony Hollow, northwest of Clarksville, Ohio. One specimen was found loose in the upper or Blanchester division of the Waynesville bed, at the Blacksmith Hollow northeast of the railroad station at Oregonia. Along Elkhorn creek, south of Richmond, Indiana, small specimens of *Columnaria alveolata*, associated with small specimens of *Columnaria vacua*, occur 14 feet below the Brassfield or Clinton bed, in the Elkhorn bed. Several poorly preserved

specimens of *Columnaria*, species not determined, are present in the lower part of the bluff on the west side of the Cumberland river, opposite the mouth of Forbush creek, in Wayne county, Kentucky, in strata regarded as of Richmond age.

Columnaria alveolata—calycina, Nicholson.

Columnaria calycina differs from *Columnaria alveolata* only in the tendency of a part of the corallites to become free and assume a more or less cylindrical shape. The corallites of this form also usually are a little smaller.

Geological position. This species was described from River Credit, Ontario, where it occurs in strata equivalent to the Richmond group. The same species was described by Rominger under the term *Columnaria herzeri*, and the statement was made that the types were found by Rev. H. Herzer, of Louisville, in the Cincinnati group, Kentucky. Specimens showing these features occur at the base of the Liberty bed north of Mount Washington, and from this point as far north as Jeffersontown, Kentucky. Their local distribution is the chief point of interest. They can be regarded as only a variety of *Columnaria alveolata*.

Columnaria vacua, sp. nov.

(*Plate XI, Fig. 2.*)

Associated with *Columnaria alveolata* in the great coral reef at the base of the Liberty bed in Jefferson, Bullitt, Nelson, and Marion counties, Kentucky, is a species in which the septa are represented by sharp striæ rather than strong plates. These striæ line the inner walls of the tubes, or corallites, and usually become indistinct at the margins of the horizontal diaphragms. In other respects this species is identical with *Columnaria alveolata*.

This species is listed by Nickles as *Columnaria halli*, Nicholson. The latter, however, is a smaller celled species from a much lower horizon. *Columnaria vacua* also frequently has been regarded as merely a different state of preservation of *Columnaria alveolata*. In that case, however, it is difficult to explain why the absence of conspicuous septa should be constant in large coral growths several feet in diameter, contiguous to others showing conspicuous septa, or why certain horizons should contain numerous

specimens of *Columnaria vacua*, while others, possessing the same geological features, several feet farther up, should contain chiefly *Columnaria alveolata*. The constancy of the same features throughout the corallum in the case of large specimens at numerous localities and at several horizons scarcely could be due merely to a different state of preservation.

Geological position. Base of Liberty bed, at Bardstown, Kentucky, and at numerous other localities at corresponding horizons in the counties mentioned above. At the base of the Liberty bed, this species may be traced from Jefferson to the center of Casey county. They occur at the same horizon 4 miles north of Richmond, and at various localities between Stanford and Crab Orchard. At the base of the Saluda bed they occur from Hanover and Madison, in Indiana, northward to the northern edge of Jefferson county. One specimen of *Columnaria*, referred to this species, was collected immediately above the *Hebertella insculpta* zone, at the base of the Liberty bed, at Concord, Kentucky. Near Clarksville, Ohio, one specimen was found 18 feet below the top of the Waynesville bed, in the Blanchester division. Along Roaring Run, in Warren county, Ohio, one specimen was found in the Liberty bed. Along Elkhorn creek, south of Richmond, Indiana, small specimens were found 15 feet below the Brassfield or Clinton bed.

Rhynchotrema inæquivalve, Castelnau.

(*Plate VII, Figs. 10, A, B, C.*)

This is the shell described by S. A. Miller in the *Cincinnati Quarterly Journal of Science* (vol. 2, p. 60, 1875) as *Trematospira quadriplicata* and later referred by him to *Rhynchotreta*.

Compared with *Rhynchotrema increbescens*, Hall, from the Trenton of New York, the beak of the pedicel valve appears more erect, the middle part of this valve is more flattened, and on lateral view the anterior parts of the brachial valve appear more obese. The radiating plications are less numerous and more prominent. The number of radiating plications on each side of the fold usually does not exceed five, and frequently is reduced to four. Of these the three nearest the fold are conspicuous, and the remaining one or two are much less distinct. The concentric striations frequently are rather distant, and present an imbricating effect.

Typical *Rhynchotrema inæquivalve* belongs to the group having more numerous lateral plications, the middle parts of the pedicel valve are less flattened, and the beak is less erect.

Geological position. Common in the Paris bed wherever typically exposed in Kentucky. The most northern localities are at Drennan Springs and at Cynthiana. On South Benson creek, and at Frankfort, in Franklin county, it occurs also in the upper part of the beds containing *Prasopora simulatrix*, the characteristic fossil of the Wilmore bed.

Rhynchotrema manniensis, sp. nov.

(*Plate VII, Fig. 4.*)

Mature specimens of this species become full as gibbous as *Rhynchotrema capax*. In one specimen with a length and width of 14 millimeters, the gibbosity or extreme dimension perpendicular to the valves was 19 millimeters. This is a gibbosity in excess of that normal for *Rhynchotrema capax*. *Rhynchotrema manniensis* is a much smaller shell, it appears to be more compressed laterally, and has a greater number of lateral plications. Of these plications there are about 7 to 9 on each side of the median fold in case of the brachial valve. The sinus of the pedicel valve usually is narrower, relatively deeper in front, with more abrupt limiting slopes. As a matter of fact, however, the chief difference is one of size.

Geological position. In the Mannie shale, forming the upper part of the Richmond formation about three quarters of a mile west of Riverside, Tennessee; the exposure is located west of the home of Mr. Howard, on the road to Flat Woods, east of the mouth of Trace creek. It is found at the same horizon at Clifton, at the Maddox Mill on Horse creek, and also 32 miles northeast of Riverside, on Leiper's creek, a little over two miles south of Fly, north of the home of J. M. Gardner, all in Tennessee.

Leptæna gibbosa—invenusta, var. nov.

(*Plate VII, Fig. 3.*)

Width along the hinge-line about 30 millimeters; the posterolateral parts of the shell being broken away, this width is an setimate. Fourteen millimeters from the beak, the anterior part of

the pedicel valve is geniculately deflected almost vertically for a distance of 6 millimeters. The general surface of this valve is gently convex. The concentric wrinkles characteristic of this genus are almost obsolete, the wrinkles being faint but close together. About 15 radiating striæ occur in a width of 5 millimeters along the anterior margin. The middle one of these striæ is slightly more prominent. The remainder are very uniform in size, and are separated by very narrow spaces.

Compared with *Leptæna gibbosa*, James, the shell material of each valve is thicker, the striæ are more nearly uniform in size, there is no concentric depression immediately posterior to the geniculate border, and this deflected border is shorter. Moreover, in *Leptæna gibbosa* the spaces between the striæ appear relatively wider, especially along the median parts of the pedicel valve.

Geological position. At the mouth of Emily run, 2 miles west of Drennan Springs, in a series of argillaceous limestones interbedded with greater quantities of clay. The total thickness of this clayey section is 18 feet. It is overlaid by coarse limestone, 2 feet thick, followed by the Southgate division of the Eden formation. Below the clayey section containing the *Leptæna* there occurs a series of limestones, 18 feet thick, overlying the typical Paris bed with *Rhynchotrema inæquivalve* and *Hebertella frankfortensis*. The top of the limestone section below the clayey beds containing *Leptæna* is characterized by a rather coarse limestone containing a *Hebertella* with rather more numerous plications than is typical of *Hebertella frankfortensis*. The argillaceous limestones and clay section within which the *Leptæna* was found is placed at the base of the Eden formation, but not necessarily in the Economy member, whose presence has not been demonstrated in the area in question. It may be an extension of the Fulton horizon.

A small specimen of *Leptæna*, 16 millimeters wide, with a distinct geniculate border, and with somewhat finer radiating striæ, was found in the clayey section overlying the massive argillaceous limestones in the railroad cut north of Boyd, Kentucky. The exact horizon was 11 feet above the massive limestone. It here is associated with *Trinucleus concentricus*, but the horizon may be an extension of the Fulton bed. The heavy limestones at the top of the hill section east of the cut probably correspond to the heavy

limestones in the Tunnel Cut east of Carlisle, Kentucky. A similar specimen of *Leptæna* was found north of Ford, Kentucky, about a quarter of a mile before reaching the second railroad tunnel, associated with *Clitambonites diversus-rogersensis*, *Plectorthis* (*Eridorthis*) *rogersensis*, *Plectorthis* (*Eridorthis*) *nicklesi*.

Strophomena vicina, sp. nov.

(*Plate VII, Figs. 12, A, B.*)

Shell closely related to *Strophomena planumbona*. The hinge-line usually is conspicuously longer than the width of the shell across the middle, producing an outline similar to that shown by that variety of *Strophomena planumbona* which was described by James as *Strophomena elongata*. However, the brachial valve does not attain as strong a convexity and the pedicel valve usually is only slightly concave, producing an appearance closely resembling those specimens of *Strophomena planoconvexa* which have a more elongated hinge-line. Compared with *Strophomena planoconvexa*, the radiating striations are much finer, equalling in this respect typical specimens of *Strophomena planumbona*. The muscular scars of the pedicel valve closely resemble those of the latter species, but the limiting border is much less conspicuously elevated. The vascular markings of this valve usually are faint or almost obsolete, although occasionally fairly distinct. There never is a strongly raised thickening of the shell along the anterior border interiorly. Frequently the margin of this part of the interior of this valve is striated in a radiate manner. The interior of the brachial valve closely resembles that of *Strophomena planumbona*.

Compared with *Strophomena trentonensis*, from the Trenton shales of Minnesota, the shell is larger, and the outline is more extended along the hinge-line, making it less quadrangular. The shell is not wrinkled obliquely along the hinge-line.

Geological position. In the upper part of the Paris bed along the road south of the Crow distillery, on Glen creek, in the northwestern part of Woodford county, associated with *Hebertella frankfortensis*, and immediately below a layer containing *Stromatocerium pustulosum*. In a blue, fine-grained limestone thirty feet below the highest beds containing an abundance of *Rhynchotrema inæquivalve*, in the southwestern part of Frankfort,

along the road passing the reservoir. In fine-grained limestone about 10 feet below a massive contorted layer and 25 feet above Benson creek, about a mile northwest of Bridgeport, along the road to Benson station. Along the railroad, about a mile west of Benson, associated with *Hebertella frankfortensis*, and immediately underlying argillaceous, fine-grained limestone, 11 feet thick. In the upper part of the Paris bed, on the C. H. Bowyer farm, northeast of Becknerville. At the top of the Paris bed or at the base of the Flanagan chert, at Flanagan. In the upper part of the Paris bed in the quarry in the northern part of Cynthiana. About 20 feet above the Ohio river, at Carnestown, Kentucky, in strata associated with *Eridotrypa mutabilis*, *Eridotrypa trentonensis*, *Prasopora falesi*, *Prasopora simulatrix*, *Callopora multitabulata*, *Dalmanella bassleri*, *Platystrophia* sp., *Plectambonites sericea*, and *Zygospira recurvirostra*.

Hebertella frankfortensis, James.

(*Plate VII, Figs. 11, A, B.*)

(*Catalogue of the Lower Silurian Fossils, Cincinnati Group, by U. P. James, 1871; p. 10, nomen nudum*).
(*Paleontology of Ohio, vol. 1, 1873; p. 101, under Orthis borealis.*)

Radiating plications usually simple, about 40 in number, occasionally increased by intercalation near the postero-lateral angles to forty-five. Hinge-line distinctly shorter than the greatest width of the shell; the latter is found either at or slightly anterior to the middle. Brachial valve almost evenly convex, the low, broad, median fold being almost imperceptible except when the shell is seen from the anterior side. The broad, shallow, median depression or sinus of the pedicel valve frequently is much more conspicuous, although in some specimens it scarcely amounts to more than a distinct flattening of the anterior part of the valve. This flattening usually does not extend nearer to the beak than one-third of the length of the shell. The hinge-area of the pedicel valve is slightly incurved, inclining outward, the beak rising distinctly above the level of that of the brachial valve. The largest specimens attain a width of one inch.

Compared with *Hebertella borealis*, Billings, from St. Martin's Junction, near Montreal, Canada, the flattening of the median parts of the pedicel valve begin nearer the beak and the shallow

median depression toward the anterior margin of the shell is a more constant feature. The result is a general flattening of the valve. The line of junction between the valves, when the latter are viewed from the front, is more sinuous. The brachial valve is never distinctly flattened or depressed anteriorly, but frequently is elevated slightly, so as to correspond with the more distinct median depression of the pedicel valve. The close relationship of this shell to *Hebertella borealis* is undoubted.

Geological position. Common in the Paris bed wherever typically exposed in Kentucky. The most northern localities occur at Drennan Springs in Henry county, and at Cynthiana in Harrison county. It occurs also in the underlying *Prasopora simulatrix* or Wilmore bed, but here it is much less abundant, or is even comparatively rare. The specimens here figured are from the Paris bed.

Hebertella maria—parksensis, var. nov.

(*Plate VII, Figs. 6, A, B.*)

A comparison of this form with the figures of *Hebertella maria* suggests that the chief difference consists in the larger size of *Hebertel a parksensis*. The latter frequently attains a width of 25 millimeters, and specimens 28 millimeters in width are not rare. The brachial valve is much more convex toward the beak, the umbo rising above the level of a plane passing perpendicular to the valve at its cardinal margin. A direct comparison with the types of *Hebertella maria* might show other differences.

Geological position. Abundant in the Greendale division of the Cynthiana formation between Pleasant Valley and Millersburg, Kentucky, associated with *Orthorhynchula linneyi*. The type specimens were obtained at Parks Hill, directly south of the Licking river, on the railroad between Maysville and Paris, Kentucky. Similar specimens but in much smaller numbers occur as far south as the middle of Madison county, and westward as far as Woodford county. In the northwestern corner of Woodford county, one mile southeast of McKee's Ferry, *Hebertella maria-parksensis* occurs in the Perryville bed, associated with *Orthorhynchula linneyi*, 7 feet above the Paris bed containing *Hebertella frankfortensis* and a species of *Columnaria*.

Dinorthis ulrichi, sp. nov.

(*Plate VII, Figs. 7, A, B, C.*)

This species closely resembles *Dinorthis subquadrata* in almost every feature, exterior and interior. *Dinorthis ulrichi* differs chiefly in the more conspicuous flattening of the pedicel valve, the convexity at the umbo being less prominent and being confined to the immediate vicinity of the beak. In some specimens the median part of the valve is depressed anteriorly so as to form a broad, shallow sinus. The shell frequently is wider posteriorly than across the middle, producing a more angular outline, posterolaterally, than in most specimens of *Dinorthis subquadrata.* The radiating plications usually are coarser than in that species, but individual specimens may be selected which do not differ in this respect. The muscular impressions of the pedicel valve are similar in form but tend to be relatively smaller in size, occupying slightly less than half the length of the valve.

Compared with *Dinorthis meedsi*, Winchell and Schuchert, *Dinorthis ulrichi* is much larger, the pedicel valve is more strongly flattened, the shell is less suborbicular in outline, and the plications usually are coarser.

Geological position. The types are from the upper part of the Paris bed on the C. H. Bowyer farm, northeast of Becknerville, in the western part of Clark county, Kentucky. The exposures are on the eastern side of the creek crossing the farm in a southerly direction. The Flanagan chert is exposed west of the creek toward the northern part of the farm. Associated in the same layers with *Dinorthis ulrichi* are *Hebertella frankfortensis*, *Rhynchotrema inæquivalve*, and *Strophomena vicina.* It is found at the same geological horizon, also at Flanagan, in Clark county, and in the railroad cut in the northeastern part of Paris, in Bourbon county, Kentucky.

Dinorthis carleyi—insolens, var. nov.

(*Plate VII, Fig. 9.*)

A variety of *Dinorthis carleyi* occurs at various localities in Ohio and Indiana at the base of the Upper or Blanchester division of the Waynesville bed which differs from the typical form of the species only in having somewhat wider and flatter plications.

Geological position. The specimen here figured was obtained about 2 miles northwest of Miltonville, Ohio, east of the Blankenbecker farm, along Dry Fork of Elk Run, a short distance above the lower *Hebertella insculpta* zone. This lower *Hebertella insculpta* zone marks the base of the Waynesville bed from the neighborhood of Miltonville as far toward the southeast as the southern part of Adams county. *Dinorthis carleyi-insolens* has been found along this line at the crossing of the road from Middleboro to Oregonia, two miles east of Hammel, in Warren county. It occurs in the Stony Hollow northwest of Clarksville, and on Sewell's Run, southeast of Clarksville; also about a mile northwest of Blanchester; all in Clinton county. It is found also southwest of Woodville, in the northeastern part of Clermont county. A single specimen, not in situ but at the lower part of the Blanchester division was found about two miles southwest of Oxford, Ohio. In Indiana, the same variety occurs at the base of the Blanchester division, but without the presence of *Hebertella insculpta*, on the east side of Blue creek, west of Blue creek post office; at the home of Nick Senefeld, four miles south of Brookville; at the home of William Bauman, three miles southwest of Brookville; and also in Union county, opposite the home of Robert Martin, half a mile above the mouth of Silver creek.

Dalmanella emacerata, Hall.

(*Plate VII, Fig. 1.*)

In the original description of this species by Hall no clue is given as to the horizon at which the type specimens were found beyond the fact that they occurred in the shales of the Hudson river group near Cincinnati, Ohio. Usually, at that time, the term *shales* was applied by preference to the Eden beds. Later, S. A. Miller identified with this species a form found 160 feet above low water in the Ohio river, at Columbia avenue and Torence road, and in the excavation of Deer creek tunnel. The specimens from this Middle Eden horizon were figured in volume XIV of this Bulletin as *Dalmanella emacerata-filosa* (fig. 1, plate V). In these specimens, the radiating striations appear more numerous than in the types of *Dalmanella emacerata*, preserved in the American Museum of Natural History, in New York city.

The specimens most nearly conforming to the first published

figure of *Dalmanella emacerata*, namely figure 1 on plate 2 of the Fifteenth Report, New York State Cabinet of Natural History, appear to be those which were obtained from the Fulton or *Triarthrus becki* horizon, at Cincinnati, Ohio. Considering the fact that the so-called River quarries were largely operated at the time when the earlier collections were made at Cincinnati, this identification is not improbable. In favor of this identification is the coarseness of the radiating striæ; evidently distinctly greater than that of the specimen represented by figure 2 on the same plate. A specimen from the Fulton bed is figured in the present number of this Bulletin.

As a matter of fact, the type specimen of *Dalmanella emacerata*, preserved in the American Museum of Natural History, appears to be not quite as coarsely striated as these Fulton specimens, or as the first published figure.

Dalmanella breviculus, Fœrste.

(*Plate VII, Fig. 5.*)

This form would not be considered distinct from *Dalmanella emacerata-filosa*, were it not for the fact that intermediate forms are unknown at present. The shorter length, resulting in a semicircular, rather than subquadrate outline, is the chief distinguishing feature. See figure 2 on plate 2 of the *Fifteenth Report*, New York State Cabinet of Natural History.

Geological position. Middle Eden beds at Cincinnati, Ohio.

Dalmanella fairmountensis, Fœrste.

(*Plate VII, Fig. 2.*)

An enlarged figure of one of the type specimens is presented in this Bulletin, for purposes of comparison with the enlarged figures of the other forms belonging to the *Dalmanella emacerata* group.

Geological position. Fairmount bed, at Hamilton, Ohio. Found also at Cincinnati, Ohio, New Trenton, Indiana, and along the Baltimore and Ohio Southwestern railroad, half a mile east of Dillsboro station, in Indiana, at the same horizon.

Clitambonites diversus—rogersensis, var. nov.

(*Plate VII, Figs. 14, A, B.*)

This is an extremely variable species and it is difficult to determine from the specimens at hand whether it is to be regarded as identical with *Clitambonites diversus*, Shaler, or as new. The pedicel valves vary between forms which are quite symmetrical in shape, and which appear to predominate, to others in which not only the beak is excentric, but the entire valve is more or less irregularly contorted. The area of this valve is broadly triangular and varies from 7 to 8 millimeters in height; it usually forms an angle of about 100 to 115 degrees with the plane of junction of the valves, but may be inclined forward so as to form an angle of 70 degrees. The brachial valve is flat, with a broad, shallow, median depression anteriorly. The most conspicuous feature of this valve is its great width, considering its length. Several specimens 24 millimeters wide had a length of only 14 or 15 millimeters. In these specimens, the posterior adductor scars and the depressions between the cardinal process and the crural plates are considerably shorter from front to rear than in the Trenton specimens of *Clitambonites verneuili*, Billings. The anterior adductor impressions are distinctly indicated and either equal or exceed in size the posterior ones. The number of radiating striæ varies from 4 to 5 in a width of 3 millimeters.

Geological position. In the lower part of the Eden formation at Rogers Gap and also north of Ford, a quarter of a mile before reaching the second tunnel, Kentucky, associated with *Plectorthis* (*Eridorthis*) *nicklesi*, *Plectorthis* (*Eridorthis*) *rogersensis*, and a *Leptæna* similar to that found at Boyd, Kentucky.

Smaller specimens of *Clitambonites*, apparently belonging to the same variety as the preceding, occur in the coarse-grained limestone quarried about a mile and a quarter west of Carlisle, and in contorted fine-grained argillaceous limestone exposed east of Carlisle, both before reaching the so-called Tunnel cut, along the railroad, and also at the exposures immediately beyond the cut. At the latter locality the following section is seen, described in descending order:

Hard blue limestone layers, cross-bedded	4 ft.
Hard limestone with a nodular base	2 ft. 3 in.
Nodular argillaceous limestone with *Clitambonites*	3 ft. 4 in.

Solid blue limestone layer....................................1 ft. 2 in.
Nodular argillaceous limestone with *Clitambonites*....................6 ft. 6 in.
Thin limestone layers interbedded with a greater quantity of clay, not measured, approximately......................................40 ft.
Top of Cynthiana formation.

The clays overlying the Cynthiana formation carry an extension of the Fulton fauna. The extensive exposures at the Tunnel cut overlie the *Clitambonites* horizon. The relation between the *Clitambonites* horizon at Carlisle and that at Rogers Gap has not been determined.

PLATE VII.

Fig. 1. *Dalmanella emacerata.* Cincinnati, Ohio, from the Fulton bed. Magnified 1.6 diameters.

Fig. 2. *Dalmanella fairmountensis.* Hamilton, Ohio. Fairmount bed. Magnified 1.6 diameters.

Fig. 3. *Leptæna gibbosa-invenusta.* Two miles west of Drennan Springs, Kentucky. In strata underlying the Southgate member of the Eden; possibly an extension of the Fulton bed. Magnified 1.6 diameters.

Fig. 4. *Rhynchotrema manniensis.* Three quarters of a mile west of Riverside, Tennessee, in the upper part of the Richmond formation.

Fig. 5. *Dalmanella breviculus.* Cincinnati, Ohio. Southgate bed. Magnified 1.6 diameters.

Fig. 6. *Herbertella maria-parksensis.* Parks Hill, Nicholas county, Kentucky. Greendale member of the Cynthiana formation. A, brachial valve. *B*, pedicel valve.

Fig. 7. *Dinorthis ulrichi.* A, brachial valve. *B*, *C*, pedicel valves. Northeast of Becknerville, Kentucky. Paris bed.

Fig. 8. *Protarea richmondensis.* Figure of the type, enlarged 1.6 diameters. Dayton, Ohio. Whitewater bed.

Fig. 9. *Dinorthis carleyi-insolens.* Northwest of Miltonville, Ohio, in the Blanchester division of the Waynesville bed.

Fig. 10. *Rhynchotrema inæquivalve.* Lexington, Kentucky. Paris bed. This is the form described by S. A. Miller as *Trematospira quadriplicata*. *A*, lateral view. *B*, pedicel valve. *C*, brachial valve.

Fig. 11. *Hebertella frankfortensis.* *A*, pedicel valve. *B*, brachial valve. Lexington, Kentucky. Paris bed.

Fig. 12. *Strophomena vicina.* Pedicel valves. Northeast of Becknerville, Kentucky. Paris bed.

Fig. 13. *Beatricea nodulifera.* Three miles southeast of Lebanon, Kentucky. Near the base of the Liberty bed.

Fig. 14. *Clitambonites diversus-rogersensis.* *A*, pedicel valve. *B*, interior of brachial valve. Rogers Gap, Kentucky. In the strata underlying the Southgate member of the Eden formation, but including *Eridorthis rogersensis* and *E. nicklesi*, and carrying a fauna differing from that of the Economy member.

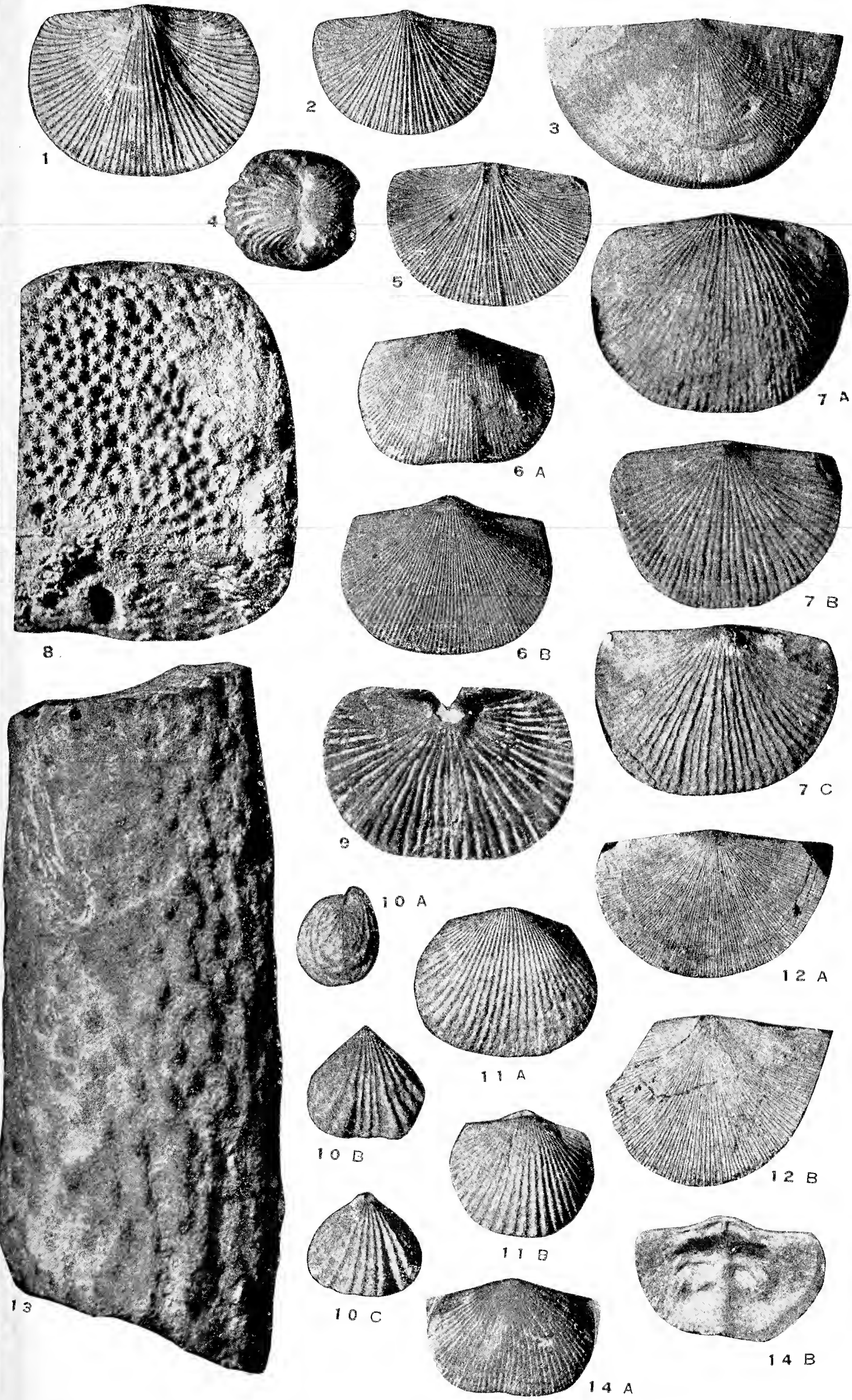

1
2
3
4
5
6 A
6 B
7 A
7 B
7 C
8
9
10 A
10 B
10 C
11 A
11 B
12 A
12 B
13
14 A
14 B

PLATE VIII.

Fig. 1. *Pasceolus darwini.* *A*, *B*, different specimens. Two miles south of Maysville, Kentucky, along the railroad. At the base of the Bellevue bed.

Fig. 2. *Brachiospongia lævis.* Figure reduced to half size. One mile north of Paint Lick, Kentucky. Near base of Mount Hope bed.

Fig. 3. *Beatricea undulata.* Bardstown, Kentucky. In the lower part of the Liberty bed.

Fig. 4. *Beatricea nodulifera-intermedia.* *A*, lateral view. *B*, terminal view of the same specimen, showing the central area occupied by large convex diaphragms, and the general mass occupied by numerous cystoid plates. Lebanon, Kentucky. Near the base of the Liberty bed.

Fig. 5. *Beatricea nodulifera.* Lebanon, Kentucky. Near the base of the Liberty bed.

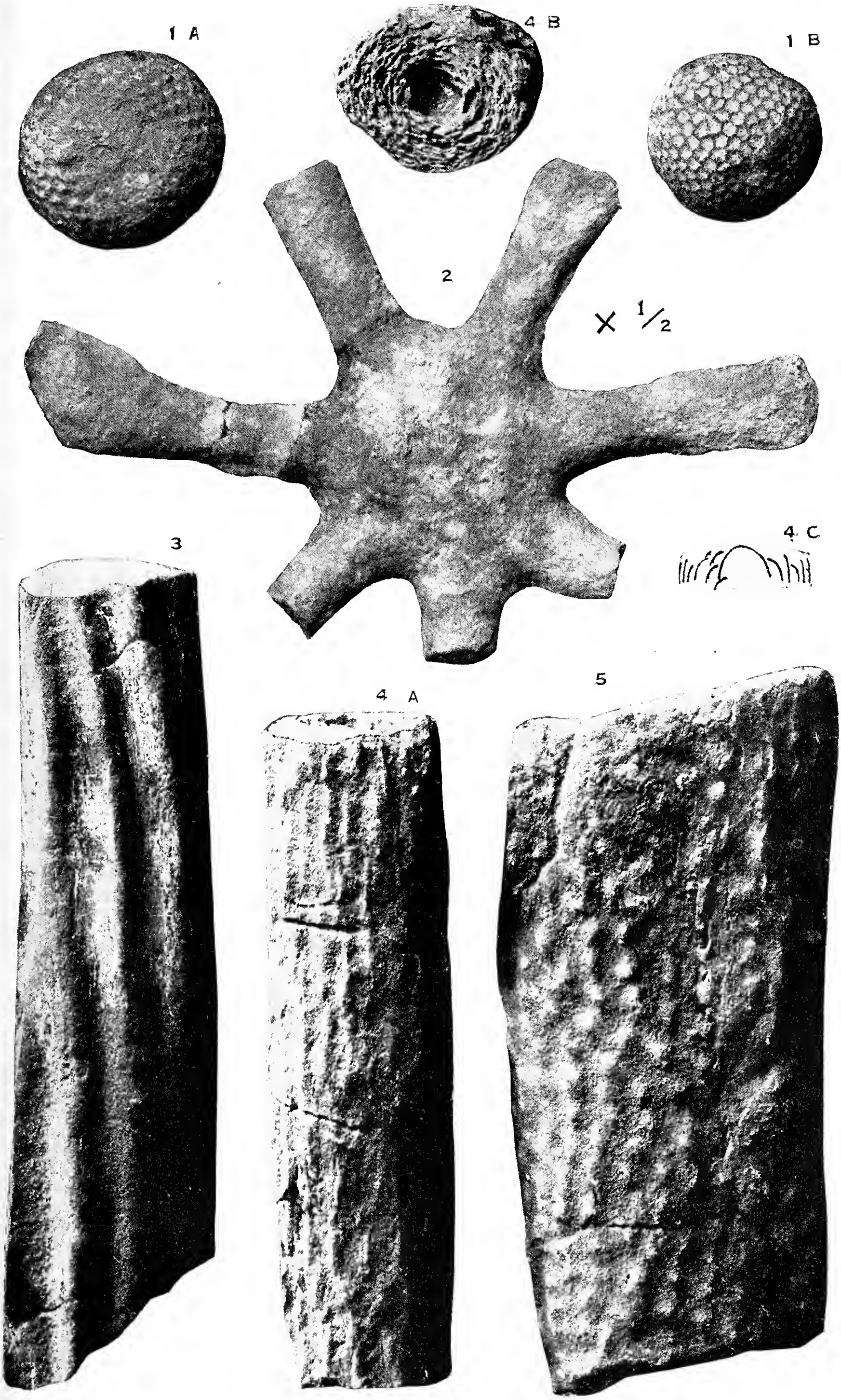

1 A
4 B
1 B
2
× 1/2
4 C
3
4 A
5

PLATE IX.

Fig. 1. *Dystactospongia madisonensis*. Madison, Indiana. Saluda bed, 7 feet above the chief *Columnaria* layer.

Fig. 2. *Heterospongia*, probably *H. knotti*. A mile and a half southeast of Lebanon, Kentucky. In the upper part of the Maysville formation below the Arnheim horizon.

Fig. 3. *Streptelasma*, apparently an aberrant form of *Streptelasma vagans*. Dayton, Ohio. Whitewater bed.

Fig. 4. *Streptelasma dispandum*. Moores Hill, Indiana. In the Upper or Blanchester division of the Waynesville bed.

Fig. 5. *Dystactospongia madisonensis*. A little over two miles south of Versailles, Indiana. Part of the surface of a lobate form, similar to that represented by figure 1. At the base of the Saluda bed, immediately beneath the *Tetradium* horizon.

Fig. 6. *Streptelasma divaricans-angustatum*. Osgood, Indiana. Whitewater bed.

Fig. 7. *Beatricea undulata-cylindrica*. Four miles north of Richmond, Kentucky. Liberty bed.

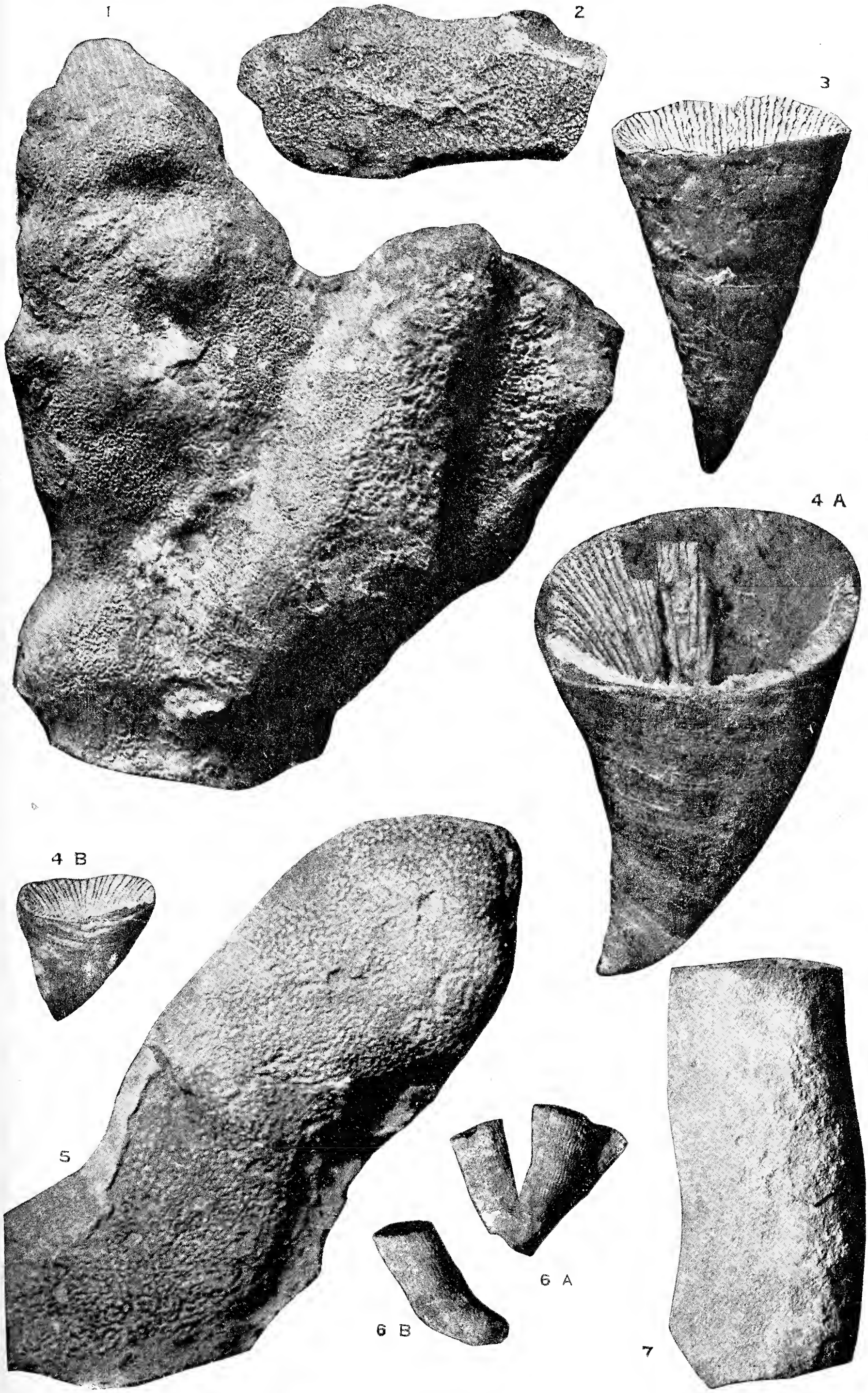

1
2
3
4 A
4 B
5
6 A
6 B
7

PLATE X.

Fig. 1. *Tetradium minus*, Safford. *A*, natural size. *B*, cross-section enlarged; copied. Mouth of Bull creek, Indiana. Richmond group.

Fig. 2. *Protarea richmondensis-papillata*. *A*, natural size. *B*, a part of the same specimen, enlarged. Encrusting *Strophomena planumbona*. Dayton, Ohio. Whitewater bed.

Fig. 3. *Streptelasma insolitum*. Walls of calyx broken off. A mile and a half southeast of Westport, Indiana. Whitewater bed.

Fig. 4. *Streptelasma divaricans*, Nicholson. *A*, the calyx of one specimen. *B*, the same, enlarged. *C*, *D*, lateral views showing calyces. *E*, a group viewed from above. Osgood, Indiana. Whitewater bed.

Fig. 5. *Brachiospongia tuberculata*, James. *A*, view of lower surface. *B*, lateral view. Both views reduced in size. The greatest dimension is 235 mm. Seven miles west of Wilmington, Ohio, south of the road from Ogden to Vandevorts Corner, along one of the branches entering Todds Fork from the west. Liberty bed.

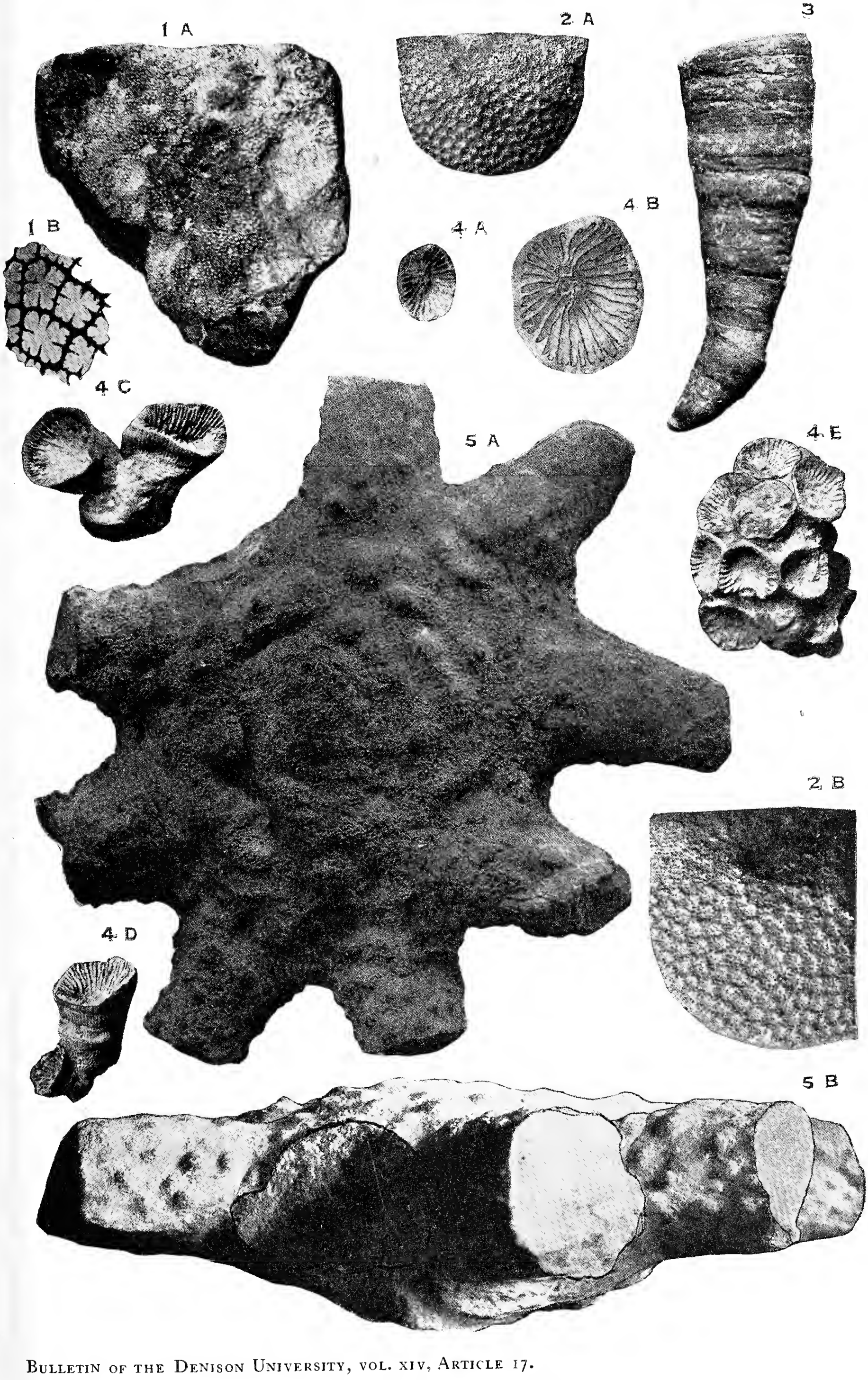

1 A
2 A
3
1 B
4 A
4 B
4 C
5 A
4 E
2 B
4 D
5 B

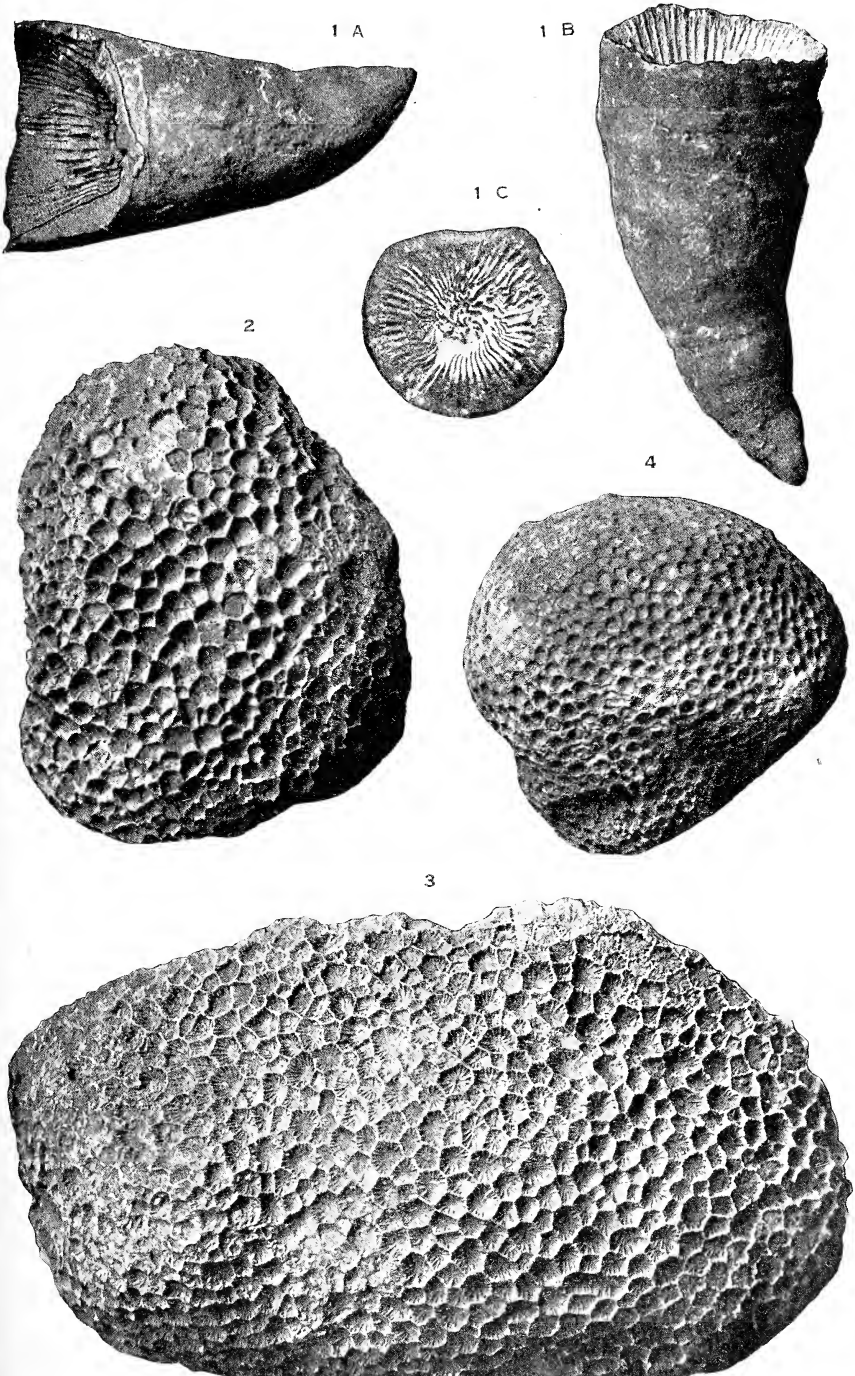
PLATE XI.

Fig. 1. *Streptelasma vagans*. *A*, lateral view, showing interior of calyx. *B*, lateral view. *C*, view from above, the sides of the calyx having been broken away, showing the twisting of the septa at the center. Dayton, Ohio. Whitewater bed.

Fig. 2. *Columnaria vacua*. Bardstown, Kentucky. At the base of the Liberty bed.

Fig. 3. *Columnaria alveolata*, Goldfuss. Bardstown, Kentucky. At the base of the Liberty bed.

Fig. 4. *Calapœcia cribriformis*, Nicholson. Bardstown, Kentucky. Near the base of the Liberty bed.


1 A
1 B
1 C
2
4
3

PLEISTOCENE GEOLOGY OF THE MORAVIA QUADRANGLE, NEW YORK.

By Frank Carney.

CONTENTS.

Physiography of the Moravia Sheet.

STRATIGRAPHY.

The rocks outcropping in this region belong to the Devonian Period, representing the formations from the Hamilton to the Portage inclusive. The higher areas bear the Portage which contains many arenaceous layers interspersing the sandy shale. The Genesee is best exposed about Montville and in the gorge of Dry Run. The Tully limestone has been cut by the Owasco Inlet valley, and may be studied to advantage along the eastern wall from a point about one mile north of Moravia southward nearly to Locke. Fig. 6 gives the contact of the Hamilton and Tully, also of the Tully and Genesee at the falls in Dry Run.

These formations disintegrate readily. The Portage contains no very heavy beds. The Tully, as shown by fig. 6, consists of several beds. This formation resists weathering better than the others, but its slight thickness, nowhere more than fifteen feet, does not enable it to form much of a shoulder or cliff on the valley wall.

THE SEVERAL CLASSES OF VALLEYS.

The valleys of this area appear to fall into four classes: (1) Those of greatest maturity; (2) those of a more recent cycle; (3) those of inter-glacial development; (4) those of post-glacial carving.

(1) *Those of Greatest Maturity:* Of the oldest valleys in the quadrangle Fall Creek is the most typical (fig. 2). The valley of this creek heads near the north margin of the quadrangle (fig. 1), possibly a little north in the Skaneateles sheet. Its exact origin is somewhat indefinite because of burial by glacial drift. The valley, however, opens towards the south and in the vicinity of McLean joins a wider valley which leads from Cortland, trending southwestward towards Ithaca. The valley of Fall Creek apparently is in topographic adjustment with this wider valley. There are also certain mature tributaries of the former valley, particularly one which heads north from Summer Hill joining the major valley south of Groton City. Other arms of equal maturity (fig. 3) may be observed.

To this same drainage cycle perhaps belong the wide contours which represent a former valley leading southwestward from

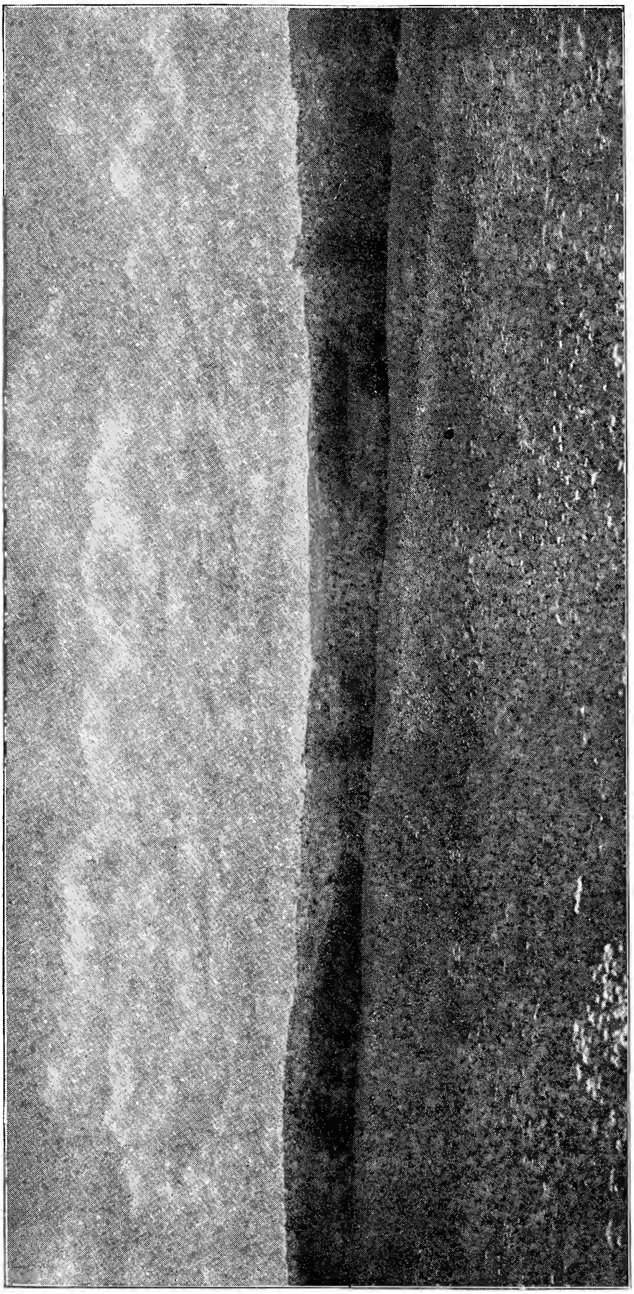


Fig. 1. Looking south through Fall Creek valley. Camera stands near high-way just east of the headwater area of Bear Swamp creek. The most distant hills lie east of Dryden.

Locke. We may call this the North Lansing-Locke valley; it has a genetic relation to Salmon Creek valley of the Genoa quadrangle, the first one west.

Possibly of the same age is the valley extending eastward, with a tributary northward, from Montville. In this connection it may be suggested that the erosion slope of the area southeast of Moravia and east of Montville indicate that the maturity about Montville possibly has a genetic association with the work of the Locke-North Lansing stream.

(2) *Those of More Recent Cycle.* Belonging to a cycle perhaps next younger than the one just described are the valleys of Skaneateles Inlet and, in parts at least, that of the Owasco Inlet. Only a segment of the Skaneateles Inlet (fig. 5) is included in this sheet, in the northeast corner. Glacial erosion has markedly altered the cross-section of these valleys as now they are in places walled by steep rock slopes; but a study of their cross-sections above the U-part of glacial erosion origin shows that they are less mature than the drainage lines considered in the preceding section.

The Owasco valley southward from Moravia to the vicinity of Peruville bears several loops of moraine and a few areas of wider morainic bands. From the study given the region it is apparent that the rock boundaries of the valley narrow about two miles north of Groton; there must have been a former divide here for there is no stratigraphic cause for the narrowing. On this supposition, the drainage which now controls this narrow area indicates a more recent period of erosion.

(3) *Those of Inter-glacial Development.* The evidence of inter-glacial erosion on this sheet is very plain in a few localities, and probably more detailed work would discover other examples; my study of the sheet has given this matter only incidental attention.

The valley in which Montville lies hangs about 200 feet above the flood plain of Owasco Inlet valley; at the southwest corner of Main and Walnut streets in Moravia a well 200 feet deep does not reach rock, so the height of the hanging is at least 400 feet. The mouth of this lateral valley has not just a single channel through which its drainage has been let down into the controlling valley; but even the contour lines show evidence of two such channels; and there is strong evidence of a third apparently buried by the massive delta gravels to the north. The road from Moravia to

Montville by way of the flour mill has for a short distance a sharp grade up over the south wall of the present stream, then relatively a gentle grade the rest of the way; this latter part of the course is a deserted channel. While I have not attempted a final study of these channels, one hypothesis is as follows: The stream is now following, in part of the course from Montville, an inter-glacial route which came into use again early in the post-Wisconsin interval by a minor tributary gradually working its way back from the floodplain at Moravia, removing the delta gravels, etc., till it captured the drainage that had been flowing through the channel now deserted. That this channel, now followed by a highway, is of post-Wisconsin origin is believed because it contains neither till nor delta gravels; it is possible that stream work since the last ice-invasion has disclosed a channel carved earlier, but not very probable.

About one mile south of Moravia is Dry Run, which rises near Lickville. For a mile in the lower part of its course this stream occupies a narrow rock-walled gorge; up-stream, the valley is more mature. Just south of the gorge segment is a wider, partly buried, rock-walled channel now occupied by a slight creek; the highway runs near this deserted course which has several characteristics indicating inter-glacial origin. This latter channel appears to correlate with the wider part of Dry Run valley, but no attempts were made to trace the buried portion.

(4) *Those of Post-Glacial Carving.* All the present gorge-cutting on this quadrangle is but a continuity of erosion that has been in force since the withdrawal of the Wisconsin ice. Along the Moravia Inlet valley, commencing at the Freeville end, we find the first of these post-glacial gorges at Peruville. This is a short and rather shallow gorge in the lower formations of the Chemung rocks. It is very probable that much of this gorge-cutting work here represented was accomplished even while the ice was near at hand. The torrential aspect of the stream is evidenced by the existing alluvial fan that is built out into the main valley at Peruville, a fan that is out of proportion to the drainage area controlled by this stream. Therefore the suggestion that the fan and the gorge represent abnormal drainage conditions.

Proceeding northward through the inlet valley the side walls are so deeply buried beneath glacial drift, and the catchment basins of the creeks so limited, that post-Wisconsin time has but

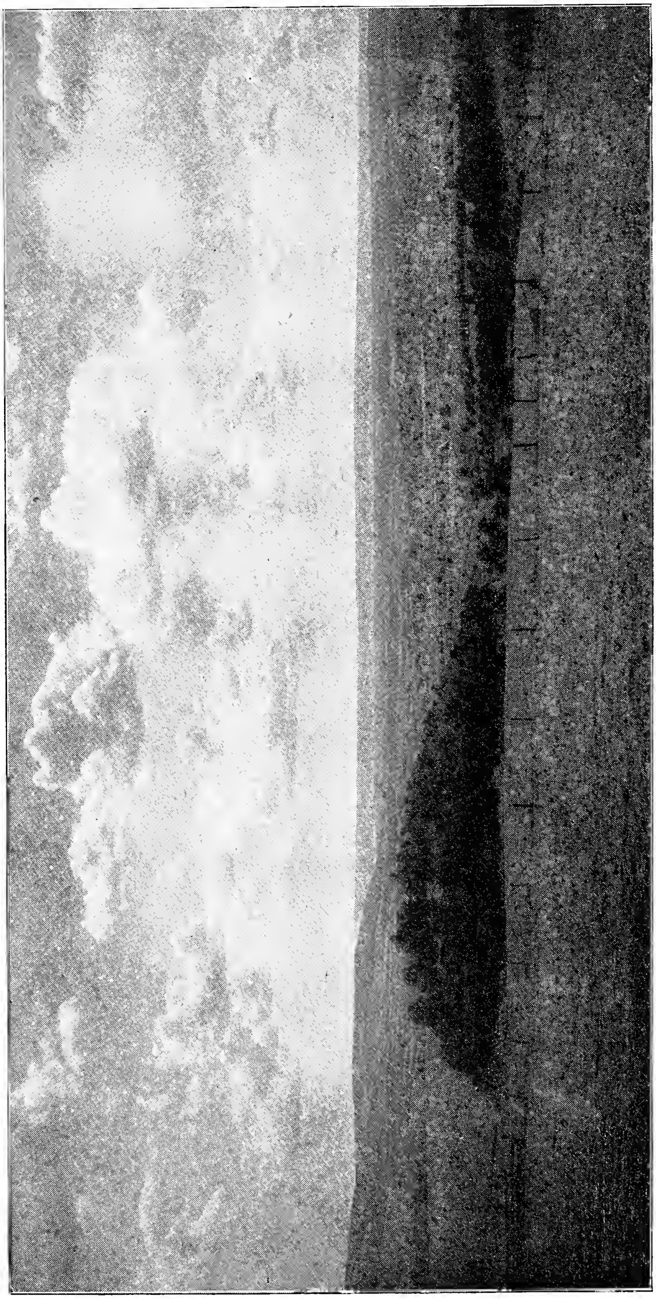


Fig. 2. Looking slightly south of west from top of the 1810-foot hill east of Freeville. Shows shape of the lower Fall Creek valley, position of the Cayuga trough, also the Seneca-Cayuga divide. The wooded and cloud-shaded area on right center marks position of the George Junior Republic grounds.

rarely sufficed to remove the drift sufficiently for much rock-cutting, so that there are no post-glacial gorges, though there are many sags or small valleys representing post-glacial stream erosion. Near Groton on the east side of the valley two streams for short distances are on rock, but this is nearly a mile from the floor of the main valley. North of Centerville we find the gorge of Dry Run (fig. 6), already alluded to. On the west slope of the Owasco valley we would anticipate many glens, since the steep fall should encourage rapid erosion, but the creeks have such limited catchment basins that they have been unable to produce any marked channels in the slopes.

At Montville the stream coming from the north flows in the last mile or so of its course, between rock walls. This stream has a fall of fifteen to twenty feet over the Tully limestone, which forms a conspicuous shoulder and is easily quarried along the east wall of the valley as far south as Locke; and a short distance down stream a slightly greater fall over hard layers in the underlying shale, the latter fall being used by the village of Moravia in connection with its electrical plant.

Northwest of Lake Como is a slight post-glacial gorge cut in some of the harder layers of the Portage sandstone. The small basin of this stream is apparently all out of proportion to the gorge-cutting here present. The explanation of the condition, however, is apparent as one follows the highway toward North Summer Hill. Just east of this village, at about the head of the valley whose gorge we are describing, is found a loop of moraine (p. 366) marking a position where the ice stood for some time. The gorge-cutting was done when the valley was carrying a burden of ice-front drainage.

About a mile east of Sempronius one passes between rock walls in following the highway into the Skaneateles valley. These rock walls cannot be connected genetically with present drainage; nor, from deductions that one would make, has the former development of drainage in the area developed the gorge. The only reasonable hypothesis for the gorge cutting here represented is that the erosion was done by ice-front waters, and this supposition is sustained by the nature of the channel which leads into the head of this rock gorge from the north (p. 432).

In the southwestern part of the quadrangle near Asbury is another gorge which presumably represents the work of post-

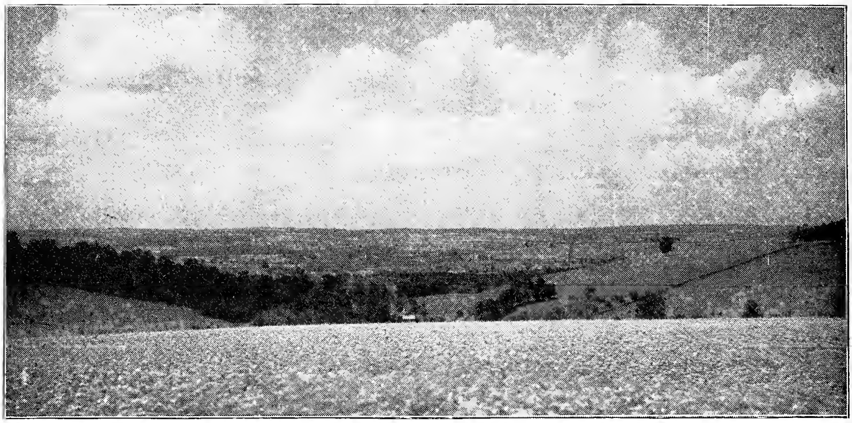


Fig. 3. Southeast of McLean is a tributary valley of Fall Creek, which heads in Cortland county. This view looks along the axis of this tributary valley, showing its flattened cross-section as well as the maturity of the major valley.

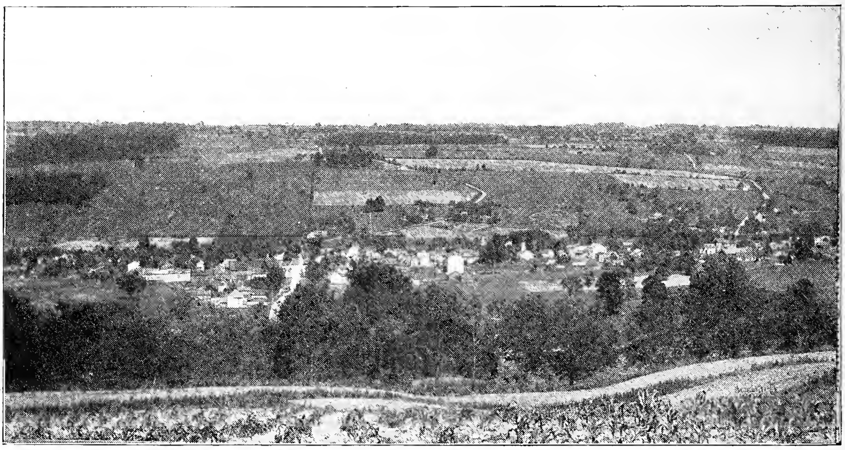


Fig. 4. Looking east across the Owasco valley at Locke; camera stands near the 1200-foot contour. Valley drift shows on both slopes.

Wisconsin waters. This gorge continues westward into the Genoa quadrangle.

In the discussion of post-Wisconsin carving it is apparent that no sharp distinction has been made between the work of immediately ice-front waters and the erosion-work of more recent streams. In all cases, except the downhill gorges associated with the glacially steepened valley walls, and the channels connected with the Skaneateles Inlet, both factors probably enter somewhat into the gorge-cutting. The Skaneateles Inlet channel, however, is purely the work of an ice-front stream.

Fig. 5. Looking north through Skaneateles Inlet valley; camera stands near mouth of overflow channel. Small portion of lake shows in middle of picture; the heavily wooded slope paralleling eastern shore marks the upper limit of more vigorous ice-erosion.

PRESENT POSITION IN DRAINAGE CYCLE.

Aside from a few post-glacial streams now in rock there is very little degradational work being done at the present time in the area of this quadrangle. Streams of this type have a local base-level due either to glacial overdeepening of the main drainage

lines of which they are tributaries, or to the work of an abnormal quantity of water which their valleys carried in immediate post-glacial times. Such channels, where topographic adjustment is in progress, exist at Peruville, a few between Locke and Moravia, at Montville, and in the short tributary valley south of Dresserville.

The base-level of the present Owasco Inlet valley is Owasco lake, which is 464 feet above the level of Lake Ontario. The base-level represented by Lake Ontario is far removed from becoming active in the drainage degradation of the quadrangle. Fall Creek, a tributary of the Cayuga valley over the eastern wall of which it now drops[1] at Ithaca, controls a large portion of the Moravia quadrangle. But the base-level represented by the water in Cayuga valley initiates a new drainage cycle for such parts of the quadrangle as are drained by Fall Creek. A recent cycle is also in operation for the valley tributary to the Owasco Inlet at Moravia. In all other respects this quadrangle occupies a prematurely advanced stage in its drainage cycle. The former major drainage line, that is, the valley now controlled by the Owasco Inlet, in its southern part has been so aggraded by glacial deposits that many of the streams which preceding the ice invasion were doing erosional work have in the main ceased to be agents of disintegration. This glacial interference with the erosion cycle is the same in kind as has become operative in all of these Finger Lake valleys. It becomes apparent, therefore, that one of the results of glaciation is the hastening of the position which drainage in its normal development would have brought about. On the other hand, certain upland valleys contiguous to these major drainage lines have been started on an entirely new cycle through the erosive work of ice in the longitudinal valleys to which the upland valleys were pre-glacially graded.

Distribution of the Drift.

general discussion.

In accounting for the veneer or for the deeper accumulations of drift found in glaciated countries, one considers both the local topography and the topographical aspect of probably all the area

[1] R. S. Tarr: *Am. Geologist*, vol. xxxiii (1904), pp. 271–91.

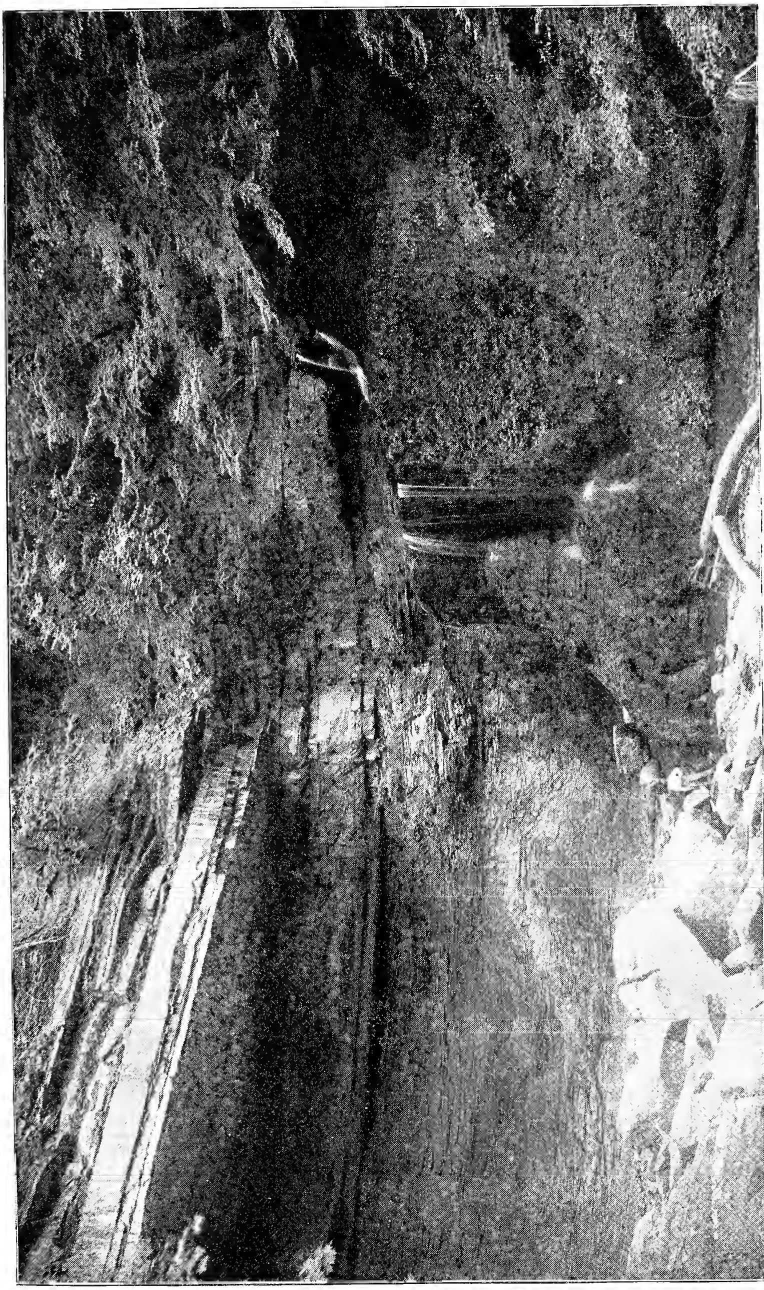


Fig. 6. A water fall due to the Tully limestone south of Moravia in Dry Run. Contact of Hamilton and Tully.

which intervenes along all the lines of ice movements between the region under discussion and the dispersion centers of the ice. The load which an ice sheet acquires doubtless depends in the first place upon the irregularity of the surface over which the ice is moving, and in the second place upon the attitude of that surface in reference to the dispersion area: that is, ice moving down a slope does not perform the abrasive work conducive to the acquirement of a great amount of débris, whereas ice moving against a slope is apt to take on much more rubbish. The lithological aspect likewise of the country being traversed is a factor of considerable importance. This factor enters into the question in two ways: (1) Stratigraphical terranes that are easily denuded either by erosion or by abrasion suffer more from an ice cap than do terranes that because of structure are less easily influenced by these agents. (2) On the other hand, the attitude of the rock formations regardless of the general slope of the country is a control in the acquirement of a load by glacial ice. In much the same manner, but to a less degree, the abrasive work of ice is accentuated when the movement is against the dip of the rock. It has been noted that on coasts where the rocks dip seaward, wave work is less effective. The analogy between the erosion of waves and ice may not be close; nevertheless there is a similarity in the mechanical principles involved.

It is apparent, therefore, that a cross-section of the ice sheet transverse to the axis of movement would reveal an irregular distribution of débris. This irregularity is due largely to the factors already discussed, that is, the topography, and the attitude and structure of the rocks over which the ice has moved. If the local topography were not a factor in the final disposition of drift by an ice-sheet, then any given moraine of an area would be the counterpart of the termini of the lines of rubbish carried by the ice at the time of that halt.

This consideration as yet has neglected the fact that ordinary ground moraine is the sum total of débris in the ice that finally covered the area of this moraine. The ideal example of such drift-accumulation is seen only when some portion of an ice-sheet becomes stagnant and decays. Then the load of drift in this stagnant ice will have, after melting, about the same areal distribution that it had when enclosed in the ice. So it follows that a considerable area of detached ice might be marked by an accu-

mulation of deposits corresponding to the points where the drift was localized in the ice. Only in limited areas, perhaps, is any ground moraine due to this combination of conditions.

When the ice-melting and the ice-supply are about equal the resulting accumulation of débris is simply the piling up at the ends of the lines of ice movement of such quantities of drift as the ice holds along these lines. The most typical illustration of débris thus assembled exists in the areas of thickened drift called terminal moraines, and along valley lobes and tongues which deposit drift known as lateral moraine and loops. Such bands represent the débris gathered by the ice along its paths of motion.

Furthermore, the upturning of layers in the ice results in shifting laterally considerable débris that otherwise might reach a distal position in accordance with the conditions mentioned above. This phenomenon has been observed in Greenland in both the ice-cap and the dependencies.[2]

The other great factor in the distribution of drift is found in the relief of the region under consideration. This control works itself out in two ways; first, the local topography to a large extent establishes the course of ice-front drainage; second, this local topography gives the ice-front its particular form. I will discuss these points in reverse order.

The influence which topography has on the outline of the ice-front is a question that can be unraveled largely through mapping the drift. Certain theoretical considerations, however, are of aid, since a semi-plastic body naturally assumes forms consequent upon the outlines of the area over which it rests. The ice will feed out farther along the more deeply incised valleys, and will be hindered in its progress by the highest divides. It follows, then, that if a given region contains valleys longitudinal to the direction of the ice-feeding, these valleys will each be occupied by a tongue or lobe of ice. When the ice with this irregular front maintains a fixed position, the feeding and the melting being about equal, drift accumulates in lines along its borders.

If, however, the area has slight relief, then the form of ice-front will reflect more nearly the lines of impulse of the ice-sheet. This principle would give us in a fairly level country a uniform ice-

[2] R. D. Salisbury: *Jour. of Geol.*, vol. iv (1896), p. 791. Chamberlin and Salisbury: *Geology*, vol. i (1904), pp. 282–83.

front, and the drift which accumulates from such an ice-front would take somewhat the outline of an arc whose ultimate radii converge towards the dispersion centers of the ice. But it is rare that the dispersion centers so completely control the outlines of the ice in distant parts. With an expanse of intervening lowlands and highlands, the original impulse suffers so many deflections that the resultant lines of movement in distal areas betray this impulse in only a slight degree; consequently when we are dealing with an area quite removed from the ice-dispersion centers, as the St. Lawrence-Susquehanna divide region is, this latter factor may be largely neglected.

Nevertheless the topographic influence exercised by the Ontario basin, inducing in the ice, once at least in its progress and once again in its retreat, a marked lobation, is a feature so pertinent to the whole matter of drift distribution to the south as to warrant some consideration. The general features of the Ontario lobe have been understood by glacialists, with a fairly apt appreciation, since Chamberlin's[3] work on the moraines of the "Second Glacial Epoch." The contributions to a study of the control exercised by this lobe, made by Gilbert, Spencer, Taylor, Tarr, Fairchild, and others, constitute an inclusive study that gives certainty to a paper which concerns the smaller dependencies or valley lobes of this larger body of ice. The Ontario lowland formed as it were a great reservoir which insured a degree of constancy in the position of the ice as it reached southward through the Finger lake valleys.

From a study of existing ice areas, it is probable that cyclic and climatic factors manifested themselves in the pulsations of activity shown by the continental ice-sheet. The variations of the smaller glaciers of Alaska, of the Alps, and of the dependencies to the Greenland ice-cap, all point to irregularity in the rate of feeding of the ice. When a given region lies leeward of such a basin as the Ontario area it is evident that these cyclic or seasonal variations will be less manifest, the intervening low section acting as a reservoir. In a similar manner rivers are subject to control in their flood seasons. Because of this fact there probably were fewer important local readvances of the ice in the Finger lake region than in such topography as is found in the upper Mississippi valley.

[3] U. S. Geol. Surv., Third Ann. Rep. (1883), *Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch.*

DRIFT IN VALLEYS.

The stationary position of ice tongues or lobes in valleys is generally marked by a loop of drift. The development which such loops across valleys may attain is dependent upon the following factors:

(1) *The Load Carried by the Ice.* It is needless to say that ice which contains no débris fails to register the position of its front. It is equally apparent, however, that in a topography of even slight relief the ice while passing over it accumulates some material so that where dissection has produced valleys maintaining tongues a halt of even short duration will be marked by drift; and that greater surface inequality, and a slope of the valley floor toward the ice, thus offering obstruction to its progress, furnish the conditions requisite for the deposition of thicker loops of drift.

(2) *The Grade of the Valley.* The velocity of ice-front streams, and consequently the load that they are capable of transporting, depends on the slope of the valley floor. When these streams have slight velocity the débris gathering from the ice is more apt to be transported and deposited as a valley train. A sluggish stream, or a slackwater condition in front of the ice, offers a favorable condition to the building up of a valley train. Probably the topographic association, on the supposition that the ice contains a good load of rubbish, most conducive to the development of a valley-loop, requires also a gentle slope, and a corresponding low velocity in the streams leading away from the ice. A valley tongue which extends into a static body of water, as was very often the case in the Finger lake region, should be marked by conspicuous frontal accumulations of drift. In this case wave work, and the tendency of the finer débris to be carried off in suspension, are factors that in no wise antagonize the formation of heavy loops.

(3) *The Time Factor.* The degree of development of this form of drift is directly controlled by the length of time that the ice maintains a permanent position: in other words, the period during which the melting and feeding factors are about equal. Even this condition requires a little closer analysis since it is evident that a low rate of ice-feeding accompanied by equally slight melting, thus insuring a permanent position, destroys a minimum of ice; a thickened loop of drift in most cases represents the decay of much ice. Therefore, when the ratio of feeding and melting,

both factors being active, approximates unity, we have the combination most favorable to producing valley loops.

(4) *Texture of the Drift.* The nature of the débris being accumulated likewise exercises some control over the development attained by the loop. This control is shown more perhaps in the form of the loop. The coarser the material being assembled, the higher will be the loop. When the drift contains a large percentage of clay, which when moist has a tendency to slump, the loop will be low but broad; when the drainage of the valley is ponded, this slumping will be more pronounced; but even in the absence of static waters, which induce a genetic broadening of loops, postglacial weathering tends to flatten them if much clay is present. Likewise the condition of its gravel content, whether fine or coarse, if sufficiently abundant, manifests itself in the slope of the loop.

THE OUTLINE OF VALLEY LOOPS.

Since this form of drift marks the front of the ice, it is evident that there are controls to which the shape of the ice-tongue itself is subject, and which in ultimate analysis determine the outline of the loop:

(1) Obviously the *width of the valley*, a feature contingent upon stage of development and upon the stratigraphy, will give two types of loops. In a valley of gently sloping side walls, the form usually found in areas of fairly homogeneous rock structure, the loop formed is more symmetrical. It consists of two divisions, the flood plain segment, and the lateral segments. When the valley is wide, the flood plain segment is relatively narrower, a condition due to the tendency of the ice-tongue to protrude along the axis of the valley. The lateral segments consist each of two arcs. The portion higher up the valley wall has a longer radius, i. e., slighter curvature, than the portion near the flood plain segment. It is apparent that the arc of the loop flattens as we pass along it in either direction from the axis of the valley.

But valleys having steep side walls, a condition due either to lack of maturity or to less resistant rock in which the valley is floored, underlying a more resistant formation, tend to shorten the arc of the flood plain segment of the loop; that is, the portion of the loop in the bottom of the valley is narrower than in the former case.

(2) It appears furthermore that the course taken by a loop in crossing a valley depends also on the *depth of the valley*. In deep valleys which have gently sloping side walls, the tongue of ice reaches farthest ahead of the main ice-front. Consequently the loop formed is more symmetrical, the lateral segments being many times longer than the flood plain segment. The lateral segments likewise drop so gently into the lowest part of the valley that they present a diagrammatic[4] appearance. It is evident, therefore, that this control is better illustrated in mature valleys, such as those now occupied by the Finger lakes.

(3) The form of loop may also reflect a *lack of symmetry* in *the cross-section of the valley*. It not infrequently happens that a spur of one side-wall is opposed to a gentle slope on the opposite side. A cross-section of the valley at this point gives unsymmetrical slopes, and exerts a control on a loop developed there. Such a control gives the drift-loop on one of its sides a very straight or ridge-like appearance, the direction of the ridge marking the axis of feeding of the ice-tongue.

(4) *The relation sustained by the valley axis to the direction of ice-movement* will also have an influence on the general outline of valley loops. Usually the topography exerts a strong control over the direction of ice motion along its more attenuated front, but this control is effective up to a certain relation of these axes, beyond which the direction of motion of the ice sheet decides the course taken by the loop in crossing a valley. Thus it happens that a loop, near the point of junction of two or more fairly mature valleys, may sustain a position anywhere between coincidence with the axis of the valley and at right angles to this axis.

(5) *The influence of marginal streams*, as described by Tarr,[5] is frequently shown in the lateral segments of loops, producing sometimes a lopsided development. Slight oscillations of the ice-front cause a shifting of streams lateral to the valley lobes; both the erosion work of these streams and their unequal deposition of load tend to the asymmetrical development of loops.

[4] R. S. Tarr, *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 218.

[5] *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 222.

VALLEY LOOPS OF THE MORAVIA QUADRANGLE.

The generalizations in the above section have been deduced from a study of the loops detailed below:

(1) *In the Freeville-Moravia Valley.* It is recalled (p. 340) that this valley is probably composite in origin. At present it conveys through-drainage to the north from about the area of Freeville; in the genesis of this valley a divide doubtless formerly existed a mile or so north of Groton, from which water flowed in either direction. This constriction in the rock-confines of the valley had some slight effect at least upon the outline of the valley tongue which occupied the Freeville-Moravia area during the retreatal halts of the ice. The general direction of the valley is quite accordant with the general direction of ice motion. This fact accounts for the many typically developed loops found in the valley.

"A." Extending southeastward from the vicinity of the George Junior Republic is a conspicuous ridge of drift, shown in fig. 7. The massiveness of this ridge taken into consideration with the great accumulation of drift contiguous to it, but slightly to the north, with also the thickened drift southward from Freeville against the south wall of the old Fall Creek valley (See Dryden Quadrangle) indicates a rather long halt of the ice. By consulting the combined topographic map it is observed that a mature valley extends northward towards the Freeville area from the direction of Dryden lake. This mature valley during several stages of the ice retreat carried valley dependencies whose positions may now be read from the loops, but when the ice had retreated northward to the position occupied when the loop under discussion was being developed, the front of the ice did not extend to the southeast into this old valley, but maintained a general north-south line across the mouth of the valley. In other words, the general position of the ice in the Moravia area at this time reflected the larger control being exerted by the lowland of the Cayuga valley. In this Cayuga valley the ice then reached much farther south than Freeville, so that the halt connected genetically with the loop under discussion was contemporaneous with a halt several miles south of Ithaca.

An examination of this loop shows that it contains a large percentage of clay, with some gravel. That this loop had a genetic

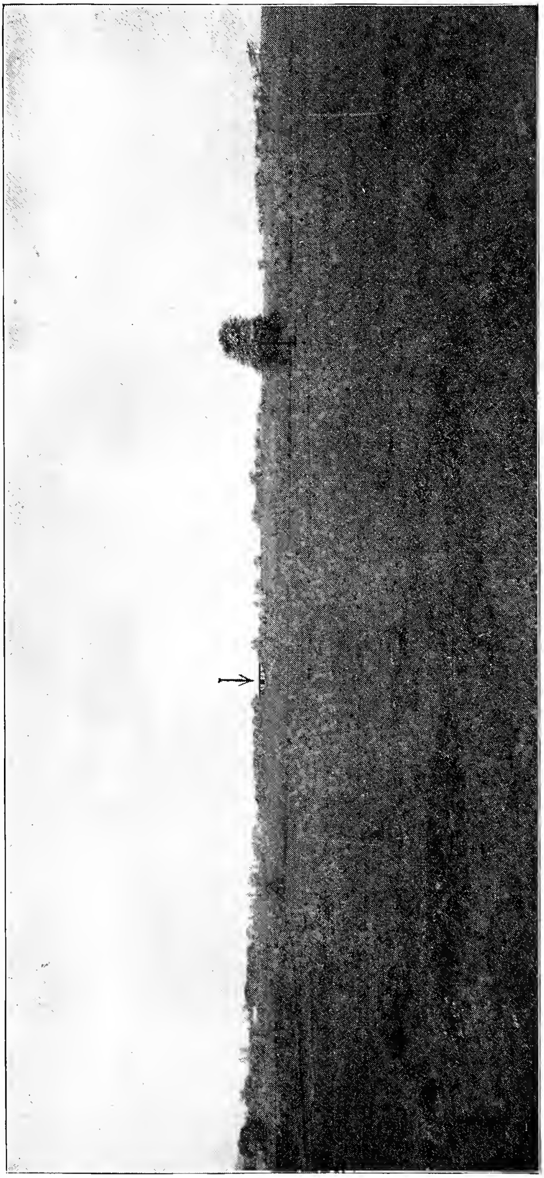


Fig. 7. Loop "A" from the east. Camera stands near northern margin of the Dryden sheet, and points a little south of west. The arrow indicates cut made by railroad in this loop.

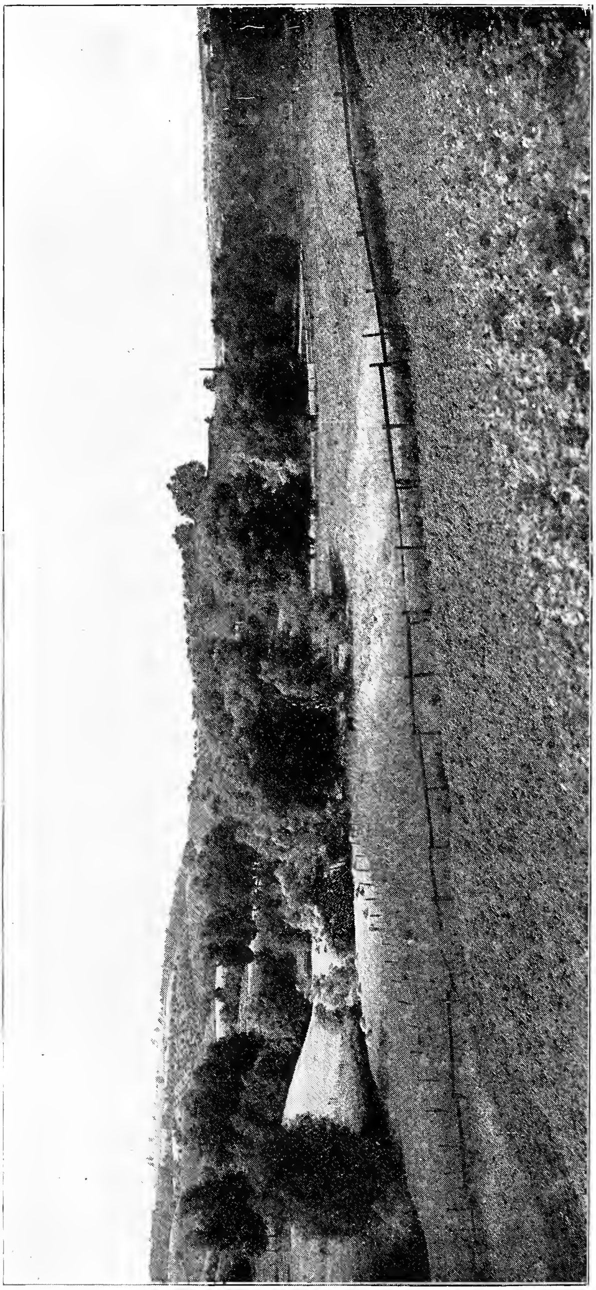


Fig. 8. West segment of loop "E" viewed from south. Loop blends into drift covering valley wall near left margin of view. Just to right of smokestack the loop has been cut by a stream; the west end of the other segment shows on extreme right. Sag-and-swell valley drift appears in foreground.

association with the conspicuous kame-area at Freeville and northward is a question discussed in another place.

"B." Just north of Freeville where the recently constructed highway reaches westward across the valley one notes an inconspicuous accumulation of drift, suggesting a temporary position of the ice. This drift does not average over eight feet above the general outwash plain, but the alignment of scattered knolls indicates that the ice halted here briefly at least. The outwash gravels of a later ice-halt, and wave work of an ice-front lake which later covered the area have rendered less conspicuous this loop which had slight initial development.

"C." At Peruville, an alluvial fan on the west side of the valley reaches out almost to the drift which flanks the opposite side of the valley. It is noted, too, that the lingering of the ice at this point probably commenced slightly south of the present southward slope of this alluvial fan, but the melting and feeding factors lacked enough of being balanced so that a rather wide, low band of drift was developed across the valley. The abundance of washed deposits into which this loop blends on the east side, where the fan has not partially buried it, is a condition that will be discussed elsewhere in connection with the fact that in this part of our quadrangle the kame type of drift apparently predominates.

"D." About half way between Peruville and Groton, the drift which all the distance covers the walls of the valley, particularly the east wall to a considerable depth, narrows down into a ridge across the valley. We have to bear in mind constantly that through a large part of this Freeville-Moravia valley, moraine terraces and other forms of valley drift are so thoroughly developed that there is a tendency to mask the accumulation which would mark the position maintained for any essential length of time by the valley tongue. This condition perhaps accounts for the fact that some of these loops are so inconspicuously developed in the bottom of the valley that their diagnosis as moraines would hardly be permissible without the association of analogous drift higher up on the valley walls.

"E". Extending across the valley at Groton is another loop which has been cut through by a drainage channel probably from its early history. The ice-front drainage maintained for some time after the ice had retreated far northward in the valley, an outlet to the south. It is thus that the ridge of drift at Groton is

not complete. As shown by figures 8 and 9 it is evident that the west segment of this loop is more conspicuously developed. In connection with this fact it may be observed that the east wall of this valley carries everywhere a great complex of drift, so that the normal condition of the east segments of nearly all the loops is a lack of distinctness brought about through the massing of drift by marginal drainage. It may be stated further that the material constituting these loops is uniformly more gravelly in the eastern than in the western segment. This fact is especially well illustrated in the Groton loop, as here the west segment consists prevailingly of till in which clay predominates, while the east segment discloses a great amount of gravel as exposed where cut into by the streets crossing it and passing over it up the slope, as well as in the pits that have been opened for road-making material, and also in the fact that the village cemetery is located on its top.

"F." Proceeding northward the present valley pinches down at the boundary line between Tompkins and Cayuga counties. Here the loop (fig. 10) is only less distinct than at Groton, and repeats the same arrangement as to the predominating constituents in the two segments. The prevalence of clay in the western part of this loop is the normal condition of the drift, not only at this point in the valley, but for about two miles to the north and rising up the slope to the west. On the other hand, the eastern segment of the loop, the eastern wall of the valley, and the adjacent uplands bear drift in which washed material predominates.

"G." About three-fourths of a mile southeast of Locke there extends out into the valley bottom from the east wall a conspicuous ridge of till whose axis of direction is not in harmony with the position of a valley loop. That the material is predominantly clay, containing many large bowlders, is evidence that the ice here maintained for some time a fairly constant position, but the direction of the ridge is somewhat puzzling. It may be suggested that this particular ridge is the resultant of erosion. If so the reëntrant angles, particularly on the north side, have lost all evidence of stream work such as would suggest this genesis for the axis of the ridge. Neither is there a catchment basin, nor at present any indication of springs that might furnish the water for the degradational work. In this connection it may be noted that just west of the present inlet stream and railway there appear beneath the

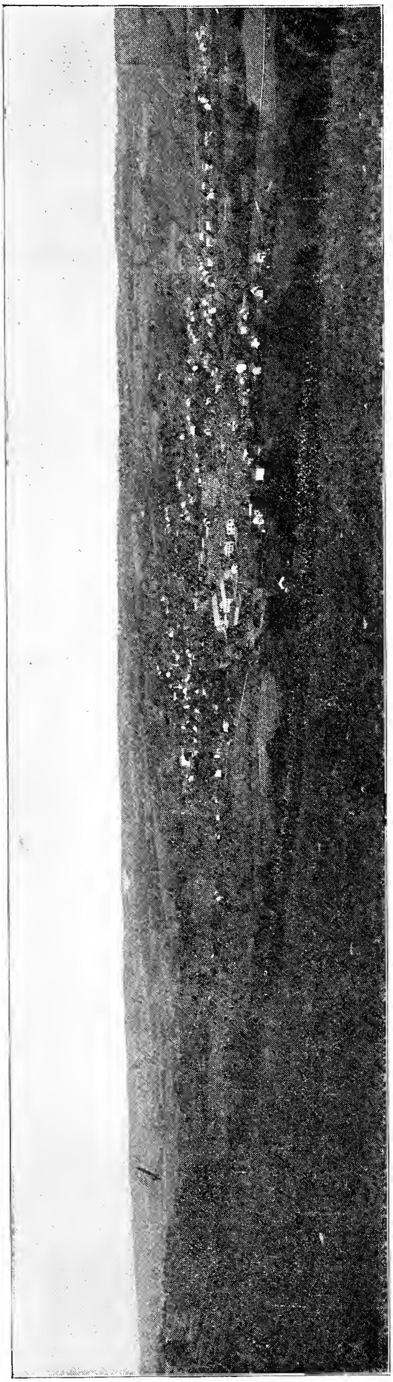


Fig. 9. Looking north of east across the Owasco Inlet valley about one-half mile south of Groton. The opposite valley wall is heavily covered with drift, locally quite kame-like. The entire arc of loop "E" (fig. 8) shows, commencing at the extreme left and blending into opposite wall northeast of the village. The arrow locates delta "B."

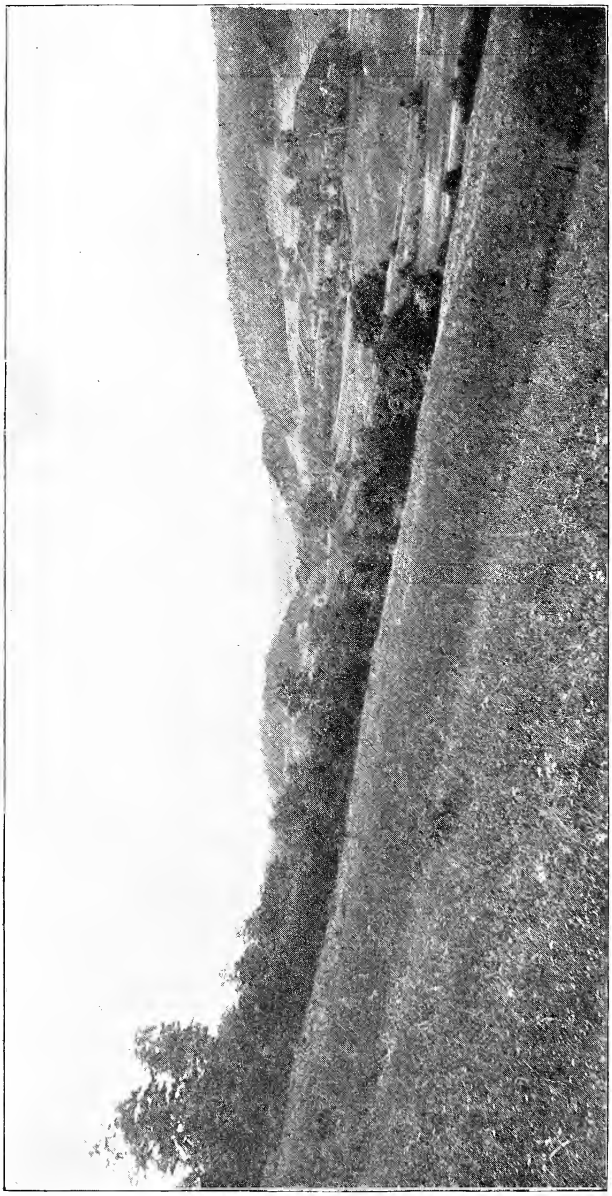


Fig. 10. Looking southward through loop "F;" the crest of the west segment of loop "E" shows in this gap. A ridge shows on right; note how all of this ridge, which is composed almost entirely of clay, save the northern end, has slumped forming a corrugated surface.

delta several exposures of till which may correlate with this ridge; the location of the deposit of till now buried by the washed material of the delta conforms to the general trend of the ridge on the east side of the valley.

"H." North of Locke, about one-half mile, reaching out from the east side of the valley, is an accumulation of drift that suggests a halt in the ice. The analogous segment on the west wall is not well developed, if it ever existed, but there is noted along this west wall a large amount of till that probably represents the slow retreat of the ice, not a permanent halt. The suggestion of a loop on the east side may on the other hand represent a concen

Fig. 11. Looking southward on the west segment of loop "I."

tration of drift, as the sections in it show an abundance of washed material from the region north and east, that is, the accumulations of lateral-tongue drainage. This area of drift was originally irregular, and stream erosion has since greatly increased the irregularity.

"I." About one mile north of this last loop a more marked frontal lobe accumulation of drift crosses the valley. On either side this loop attains a fairly uniform development, and is especially marked by the abundance of washed drift in the form of kames. This is particularly true on the western segment of the loop as appears in fig. 11. The outwash in the valley southward to the loop discussed under "H" is well developed.

Northward from this halt the ice, so far as the drift in the valley affords evidence, suffered a more rapid retreat. At any rate, no well-developed loops cross the valley; nevertheless both walls suggest a less rapid retreat of the ice in that they are fairly well mantled with irregularly distributed drift. Having in mind that the retreating ice in the region of the lakes constantly held in front of it, through several degrees of latitude, static bodies of water into which streams from the well dissected lands were pouring their load of gravel, sand and silt, and the further fact that the later ice-front lakes were of longer duration than the earlier ones, and consequently spread over their bottoms a greater amount of lake deposits, it is to be expected that mild loops, formed with the slight halts of the ice, have been largely obliterated. A long duration of such a series of factors would tend to efface the evidence of loops that formerly existed in this segment of the Freeville-Moravia valley. Furthermore, it is probable that the frontal parts of these loops were largely disseminated through the static water into which the loops were being deposited.

(2) *In Fall Creek Valley.* It is recalled from the discussion under drainage that the most mature topography of the Moravia quadrangle is found in, and adjacent to, the Fall Creek valley. We recall also the fact that at McLean this Fall Creek valley, as marked on the Moravia sheet, joins a master valley extending southwestward towards Ithaca. The maturity of development found in both the master stream and the tributary have tended to produce, during the retreating stages of the glacier, a more evenly outlined form of ice-lobe; the gently rising side walls and the preglacial width of the valley bottom give us here quite a different type of loop than that described in the Freeville-Moravia valley.

"J." In passing north and east from Freeville along the Lehigh Valley Railroad one notes in the vicinity of Red Mill the converging, toward the valley-bottom, of the massive kame accumulations, particularly those on the eastern side of the valley. A short distance north from this place, at Malloryville, the valley becomes quite completely clogged with glacial débris. The typical developed esker (fig. 18) described elsewhere in this paper is found at this place. Kettle holes and other phenomena especially characteristic of washed drift are numerous. The present stream has sluggishly picked its way through the massive accumu-

lations of drift. This marked development continues to barricade the valley almost to McLean (fig. 21) a distance of fully three-fourths of a mile. At McLean the bottom of the valley again presents the wide flood plain appearance already alluded to north-east of Freeville. This accumulation of drift represents rather more perhaps than the mere halt of a valley tongue or lobe of ice. Its general appearance, however, in crossing the valley tends to bring the drift under the category of valley loops. A fuller discussion, however, of this particular area is g ven under Kames, since the predominating type of drift in this area is the kame.

"K." Proceeding northward from McLean one notes the rather constant mass of drift that the valley carries, more especially along its western wall. The three highways that terminate in the east-west road passing through Nubia cross the drift just alluded to. The easternmost of these highways cuts through less glacial material than the other two; in fact, during the last half mile before reaching Nubia, the rock slope is slightly mantled.

At the village of Nubia, however, the position maintained by the ice-front is more strikingly shown; a wall or ridge of drift presents a convex outline as we proceed northward and for a quarter of a mile it is evident that the ice receded very slowly, as one is able to easily decipher briefer but very clear halts. Here, too, the bulk of the drift flanks the western wall of the valley.

"L." For about two miles, as we proceed northward, the drift on valley bottom and the side walls is monotonously uniform approaching Rogers Corners, east of which place there enters the major valley from the east a fairly mature tributary. The position which the ice maintained, with two tongues abutting the rock salient that extends northward between these valleys, is most plainly seen in the location of the drift ridges across the two valleys. Fig. 12 shows the appearance of a valley loop in the tributary valley; the ice-front drainage here was not as free as in the major stream. Furthermore, the topography to the east tended to concentrate into the tributary valley a large amount of drift brought by streams aligning the flank of the ice tongue; hence, the more conspicuous development of this latter loop.

"M." For the next mile northward the flood plain is not interrupted by ridges of drift, but just south of Lake Como, where the highway forks across the valley, a stationary position of the ice is read in the band of drift that intercepts the outwash.

Fig. 12. Looking southeastward from top of drift designated loop "L." This lies east of Rogers Corners in a valley tributary to Fall Creek valley.

A relationship of major and minor valleys, similar to that just described, exists also at this point. The direction, however, of the tributary valley is more normal to the major stream, and therefore has not offered as favorable a topographical position for the development of a loop.

Lake Como, an unusually large kettle lake, is bordered on the north and east (figs. 14, 15) by leveled drift hills in which gravel largely predominates. The kame-like aspect of the drift to the north and east of the lake is suggestive of the particular outline that the ice-front, as it lingered in this region, presented.

"N." For something more than two miles north of the village of Como the drift of Fall Creek valley does not indicate any long stationary halts of the ice, but near the present divide of the Fall Creek-Bear swamp drainage areas we have a well developed mass of drift which analyses itself into two or possibly three positions of the ice. The drift, however, is so irregularly dissected in part probably because of the drainage which came through this section as the ice was in the neighborhood north, and in part too because of the lateral valley slopes, that one does not feel safe in a final statement as to the several distinct positions which the front of the valley tongue may have maintained. The southern line of the next quadrangle north cuts a valley loop, the major portion of which lies within the Skaneateles quadrangle.

(3) *Other Loops Principally in Tributary Valleys.* "O." The Skaneateles Inlet valley presents a mass of drift that cannot be differentiated into loops, if they exist, without a more complete study of the region to the east which lies without the quadrangle. Fig. 13 gives a general idea of the irregular surface of the drift which buries this valley.

"P." At Dresserville there is a strong suggestion of an ice-halt. The valley here is evidently deeply buried with drift, as is shown by well sections, some distance away from its axis. But in the main, this valley, especially north from Dresserville towards Morse Mill, presents such a heterogeneous surface that one does not feel safe in interpreting the drift from a standpoint of valley loops. There are, however, some very marked suggestions, particularly on the eastern wall, of aligned deposits of drift that intimate the loop type.

"Q." At Wilson's Corners about a mile north of Montville the valley is completely barricaded by a very distinct loop. The

position maintained here by the valley tongue reflects topographic relations that exist on the north in the Skaneateles quadrangle. The outwash material synchronous with this loop has been masked by the delta and the other deposits of static water-body streams.

"R." Just east of North Summer Hill is the well developed loop, alluded to in the discussion of drainage (p.343.) The ice fed into this rather moderately developed valley from the northwest. The loop does not suggest a long halt of the ice.

OTHER FORMS ASSUMED BY DRIFT IN VALLEYS.

(1) The few suggestions already made to the problems one often meets in deciphering loops intimated the type of drift, if the distinction is sufficient to warrant such a classification, that I attempt to give in the present category. One who has been around these Finger lake valleys is familiar with the localities where drift seems to clog the valley in a manner both without system and apparently without any particular or definable position of the ice genetically contiguous to the drift. For the purposes of classification we might designate such areas of glacial débris as *massed*[6] *valley moraine*. For the formation of such drift accumulations three conditions, as it appeals to me, are requisite: (1) A period of time during which the ratio of the feeding and melting factors is a little less than unity. This condition then assures a fairly stationary position of the ice, and with ice that carries a heavy load much débris must accumulate. (2) Another requisite condition is such a topographic relation of valley floors and side walls as tend to concentrate toward the axis of the valley the load carried by the streams flowing along and out from the margin of the ice. It is conceded that an amount of water abnormal to the present drainage in similar valleys must have trended towards the ice tongues throughout the retreatal stages. This water especially during the seasons of flood would cut both the drift already deposited, eroding it in a brief space of time into roughened forms, and tend to remove more speedily the débris contemporaneously collecting at the foot of the ice walls. The pertinency

[6] Tarr discusses similar deposits under the heading "Moraine Complex in the Upper Cayuga and Seneca Valleys," *Bull. Geol. Soc. Am.* vol. 16 (1905), pp. 225–27. Professor Tarr also uses the term "morainic complex" for moraine in the uplands which does not correlate with traceable moraine bands (*Ibid.*, p. 223).

of the latter condition is dependent directly upon the slope of the valley in which the tongue lies; only when the valley slopes away from the tongue would this vigorous drainage at the axis of the valley obtain. (3) Reports of existing glaciers of a type more analogous to the lobes that characterized the front of the ice-cap often mention the tendency of crevasses to reach inward from the lateral slopes of the valley tongue. When the ice is relatively stagnant and the conditions of drainage exist as described under No. 2, these crevasses would not only be filled with rubbish, but[7] with the normal melting would be enlarged till the accumulation of débris prevented further melting. Such conditions would account for some of the ridges of drift that are so reticulated in arrangement as to make their interpretation as valley loops absurd.

Another feature of the above discussion follows as a corollary when there is a large amount of clay present in the drift. The scars of recent land-slips in the very areas under discussion show how at the present time the irregularity of the drift is being emphasized. Glacial till in which clay predominates weathers more perhaps through solifluction than through erosion, and while solifluction need not necessarily render a topography more irregular, it is evident that wet clay when moving in mass produces scar-slopes that are much sharper than the initial surface.

The best illustrations on the quadrangle of drift of this heterogeneous type exist in the Skaneateles Inlet valley (fig. 13) and in the valley southeast of Morse Mill. Milder surfaces, though similar perhaps in genesis, are noted in the Fall Creek valley north of McLean against the west slope, and northeast of Groton in the Freeville-Moravia valley.

(2) *Terraces.* Along the walls of valleys once occupied by tongues of ice are found terraces formed of materials dropped from the ice, and of débris deposited by marginal streams. During the continuance of the glacier, these deposits tended to level up the depressions between the ice and the valley wall. Whereever this marginal drainage was locally slack, or was temporarily ponded, much clay entered into the débris being collected. At the melting back of the glacier, the ice-contact face of these deposits assumed a lower angle, as shown by Watson.[8] The

[7] Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), p. 87.

[8] *New York State Museum Report*, vol. 51 (1897), p. 178, figs. 12, 13.

present slope of the marginal terraces and their evenness of front depend upon the material composing them. When clay is present in quantity the terrace is apt to be represented by a series of alluvial fan-like ridges, but disproportionately long in direction normal to the proper front of the terrace, which from a distance appear as corrugations on the valley wall. When, however, gravel is conspicuously present the terrace longer maintains its original form. The most typical illustration on the Moravia quadrangle of the corrugated slopes which may characterize terraces is seen

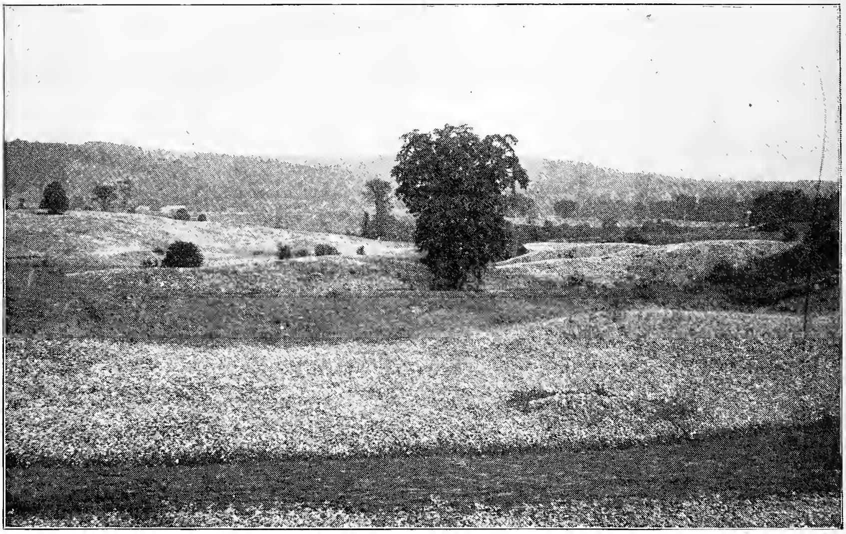


Fig. 13. Kame phase of the drift in Skaneateles Inlet valley.

towards the foot of the valley wall southwest of Moravia. At first sight it might appear that these short ridges and intervening troughs are but the normal result of erosion. A closer study on the ground shows that the clay, so abundant, has assumed this form through a long series of slippings, thus illustrating the type of weathering known as solifluction.[9]

The normal moraine terrace, as studied in valleys, has been

[9] J. G. Anderson: *Journal of Geology*, vol. xiv (1906), pp. 91–112.

so frequently and accurately described[10] that no further reference is needed here.

(3) *Ridges.* There appears in all the valleys studied a persistent form of drift which it seems most natural to classify under this heading, although the name is not at all suggestive of origin or development. They consist more frequently of till; but gravel sections occur in many of them. They vary much in length, the longest one noted measuring about one-half mile, while the general length is less than twenty rods.

In general direction these ridges are either transverse or longitudinal. As to their method of formation they may be constructional or destructional. As a general condition, however, this form of valley drift is found near the foot of the valley walls, seldom out very far in the flood plain.

One form of the constructional type is shown in figure 10. This was made of débris accumulating along the margin of the valley tongue, and consists largely of till. The northern end of this ridge resembles a kame; southward the ridge has lost its original height through slumping to both sides. A longitudinal section shows a decline from 60 feet at the north to zero at the south; the sides at the higher part slope 24° to 26°. Clay predominates in the southern part, whereas gravel increases towards the northern end of the ridge.

Another constructional form of ridge may be developed in the distal area of a valley lobe which, following a period of less activity, has developed openings or crevasses in consequence of an advance;[11] the ridges represent the concentration of débris by streams. Glacial drainage is not connected with this particular type of drift save when very near the edge of the ice. It frequently happened that tributary valleys were occupied by the lateral tongues of ice which in position were transverse to the drainage flowing from the north along the margin of the ice lobe. In this condition probably the stream for some distance had its bed over the ice which thus reached out into the tributary valley. That a super-glacial course of streams always hypothecates such an arrangement of valley lobe and lateral tongue is not implied.

[10] Chamberlin: *Third Ann. Report,* U. S. Geol. Surv. (1883), p. 304. Gilbert: *Monograph I,* U. S. Geol. Surv. (1890), pp. 81–83. Tarr: *Phys. Geog. of New York State* (1902), p. 85.

[11] Tarr: *Zeitschrift für Gletscherkunde,* band iii (1908), p. 99.

The only condition insisted upon in this form of the constructional type of ridge is that the coincidence of such a stream course and one or more crevasses would give the requisite relation of ice and a loaded stream to produce the accumulation of débris noted in these ridges.

The destructional ridge results from the erosional work of ice-front streams whose courses have been shifted either by a slight advance of the ice or by a barrier derived from a localized greater load of débris in the ice. The suggestion as to a localized condition of débris is found in the reports[12] of Chamberlin & Salisbury's studies in Greenland.

(4) *Isolated Hillocks.* A featureless outwash plain is sometimes most surprisingly interrupted by a lone hill of drift often so symmetrical in development as to suggest artificial origin. I have also seen a few such hills on the upland near the east side of the valley between Locke and Groton. They consist of both till and washed deposits, the latter being more common. As to origin, it seems reasonable that these lone hills of drift may mark the brief continuance of factors which would produce, if given more time, some of the ridges described in the preceding section; subdued moulin work might make such hills. It is not forgotten that a considerable degree of symmetry might in time be developed by normal subaërial erosion on an original mass of drift less regular in outline. The fact, however, that no constant condition as to water-laid or ice-laid drift is prevalent in these hills precludes our interpreting them as less well developed kames.

(5) *Kame Areas.* Hillocky areas of prevailingly stratified drift are formed in valleys either at the margin of the ice or back aways from the front as the ice becomes rather stagnant. Such areas are noted in the triangular plains that mark the union of mature valleys. They are likewise noted along the valley walls in the intervals between loops of drift. This type of drift in which washed material predominates has also been observed in the higher area between valleys. The promiscuous location of these kame areas tends to eliminate a topographic control as the sole factor in their genesis, though it is evident that more of such drift is found in some topographic relations than in others.

The most extensive kame-area of this sheet is found east and

[12] *Geology*, vol. i, (1904), pp. 296–97.

north from Freeville. The kames of this region have already been given a place in the literature of glacial geology.[13] While the kames here are conspicuously developed, nevertheless they are no more typical than are those formed northward in Fall Creek valley about McLean. Both well records, and sections exposed in excavations, reveal the constant presence of water in the genesis of this drift. Numerous kettle holes are suggestive of a stagnant condition of detached portions, at least, of ice. The distorted layers noted in some sections suggest either slight readvances of the ice, or slumping, following the accumulation of this washed drift.

Bearing in mind the control exercised by the Cayuga valley on the lobation of the ice-front, we are able to understand how this mature Fall Creek valley is so largely filled with drift in the area between McLean and Freeville. For the sake of emphasis in this relationship of controlling-topography and position of the ice-front in this area it is assumed that the general direction of the Fall Creek valley from McLean towards Ithaca may have been coincident, for a time at least, with the front of the ice along the eastern part of the Cayuga lobe. In this relationship we are ignoring minor tongues which were encouraged by the lesser details of topography. The existence of these minor tongues has tended, it is evident, to facilitate the accumulation of this washed drift in the region under discussion. Extending southeastward from Freeville is the Dryden valley which was occupied by a dependency of ice that gradually shortened in length as the general front of ice moved northward. That Dryden valley continued to be a factor in the outline of the ice-front even after it had ceased to be occupied by a tongue of ice is evident from the discussion already given of the valley loop which reaches southward from the vicinity of George Junior Republic (p. 354). This loop marks a static condition of ice showing that for a considerable time the general front of the glacier, approaching Ithaca from the vicinity of McLean, was convex toward the Dryden valley but did not extend into it.

Because of such a relationship then, a condition of slackened-ice-front drainage obtained during the retreat of the ice in the McLean-Freeville region. Observing the relief of the region

[13] R. S. Tarr: *Phys. Geog. of New York State* (1902), fig. 68.

to the north and east, we note a topographic environment that directed into this area of kames a large amount of drainage both along the general front of the ice and from the higher ridges towards Virgil in the Cortland quadrangle. A more or less stationary ice mass bearing a considerable load offers an added explanation for the peculiar localization of stratified drift and of outwash deposits found in the vicinity of Freeville. While this discussion has emphasized a relationship that existed for some time as shown by the valley loops already described, I am not overlooking the fact that this somewhat stationary position of the ice probably was slowly reached and as slowly receded from; during this period of gradual change a great amount of gravel and other washed material was accumulating.

While in the main I have considered the kame areas in the Freeville-McLean region as quite identical in development, there are, nevertheless, some features that indicate partial independence of origin. By consulting the topographic map we note, a short distance east of Red Mill, a slight creek that follows the sags across the irregular drift reaching ultimately out onto the flood plain. The limited catchment basin which this stream has, when considered from the standpoint of the well developed crease it occupies, proves the former erosive work of an active stream. This fact leads me to conclude that the kame area south of McLean is in part of later chronology than the Freeville kame area. The creek occupies a valley which it never could have cut with any such amount of water as might flow under normal conditions from the basins which it drains. Its more mature course has an axis which leads it westward of the Freeville kame district. In other words, the portion of the Freeville kame area that reaches nearest Red Mill was in existence when ice-front drainage cut the channel now occupied by this slight creek, and accordingly it is concluded that the conditions for drift-accumulation were present in the vicinity of McLean long after the ice had entirely withdrawn from the immediate region of Freeville. The portion of the McLean kame area which probably is contemporaneous with the first formed part at least of the Freeville kame area lies near the eastern wall of the Fall Creek valley in the vicinity of, and immediately south and east of, Mud Pond.

The connection of the Malloryville esker with the washed drift north of this village is discussed in the chapter on Eskers. It may

be said here, however, that after very detailed work in the field there appears to be no genetic association between these kames and the esker. Hills of washed drift contemporaneous in origin with the Malloryville esker lie to the west; probably a much longer esker was developed than may now be deciphered, for the reason that the kame type of drift filling the portion of the valley into which the esker leads has apparently buried a part of the esker ridge.

The striking kame topography south and west of McLean is apparently more typical for this type of drift than similar accumulations noted elsewhere on the sheet. In the immediate vicinity an ice-front lake occupied for some time this part of the valley. A delta was built into this body of water at McLean; otherwise the broken kame topography is not interrupted till we reach the flood plain deposits some distance east.

In the wide valley extending northeastward towards Cortland there is near the edge of the sheet, but more typically developed just over the boundary in the Cortland quadrangle, another area of kames. Here too, as in the Freeville region, the maximum development is on the south or east wall of the valley.

Another conspicuous group of drift hills, prevailingly washed in texture, skirts the shores of Lake Como (fig. 14). The kames of this region are not distinctly different, save in their slighter development, than the sections already described; that many of these drift knolls have been altered is evident from the photograph shown in figure 15. Apparently a static body of water stood here in front of the ice; its greatest areal extent endured pending the cutting down of its outlet through the driftloop just south; lake Como is the remnant of this larger lake. The level of the former lake coincided approximately with the tops of many of the drift-hills; waves attacked the drift distributing the products; the process continued as the outlet was lowered; accordingly many of these knolls now present a very flat-topped appearance.

In this section, too, an esker of sharp development leads southwestward from a slight kame area near the road crossings designated Como.

The massed drift which now constitutes the divide between the headwaters of Fall Creek and Bear Swamp Creek is, in localities, very kamy; but the water-laid deposits are not sufficiently developed to designate the region as a typical kame area.

Along the east wall of the valley north of Groton the general drift in areas consists prevailingly of washed materials in rounded knolls, and sometimes more strongly developed. This is especially true in the vicinity of the loop near the boundary line of Tompkins and Cayuga counties. In this region, and for three-quarters of a mile east, the kame aspect of the drift predominates.

Again, on the east wall of the valley near Locke (fig. 4) the highway leading to Summer Hill passes through very strikingly developed hills of washed drift. The topography here indicates

Fig. 14. Looking westward over kame deposits north of Lake Como.

slackened drainage, as at least a temporary condition, of ice-front waters.

A mile or so west of Locke in the vicinity of Goose Tree the water-laid content of the drift is so conspicuous as to intimate conditions that produce the kame type of deposit. This may be said of much of the drift of this area, both south and west, and southwest to North Lansing.

About a mile east of West Groton the front of the ice, in this broad divide area, offered the right relationship for producing a predominance of water-laid drift. The moraine band here for

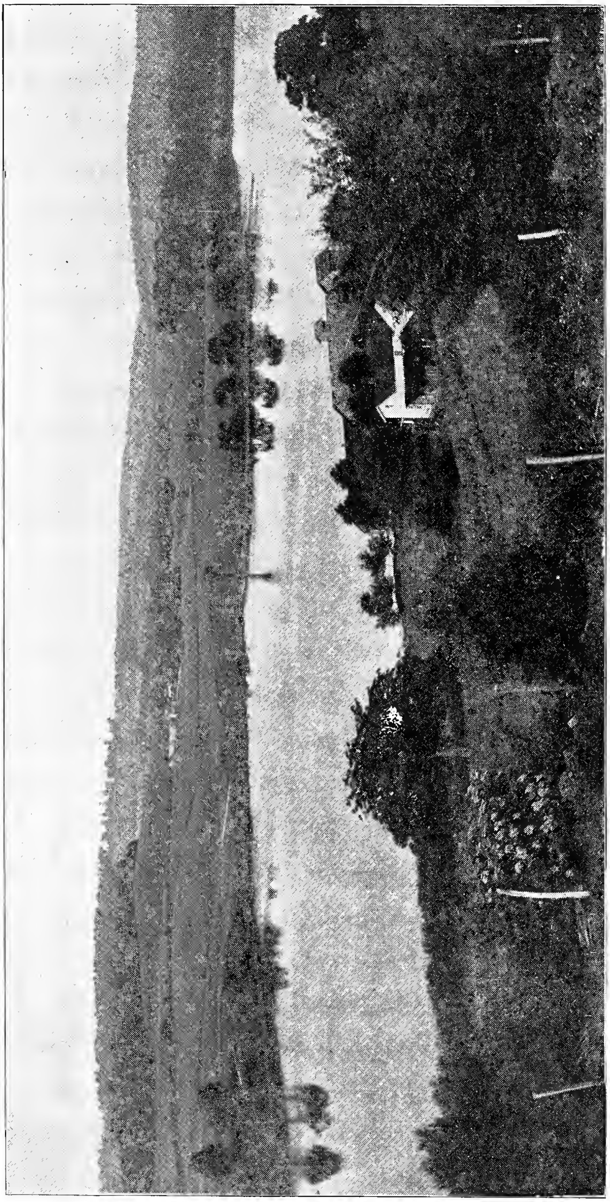


Fig. 15: Looking eastward over Lake Como. In line with the house in foreground is seen an area of even surfaced drift. To the left of the buildings across the lake is seen a portion of the kame area shown in fig. 14.

some three-quarters of a mile is very kamy both in surface appearance and in texture.

From Benson Corners the drift for one and one-half miles south and east is made up of a maze of water-laid hills, (fig. 16), most irregularly distributed. Locally this belt of moraine is over one-half mile wide. Also, the kame aspect is very marked along the ice-front southwestward toward Asbury.

In the vicinity of West Dryden the kame type likewise characterizes the drift. Indeed, the isolated areas in which water-laid moraine prevails are found irregularly scattered about the whole sheet.

In this rather detailed inventory but two more particular localities need be mentioned. Immediately westward from Fitts Corners the kame aspect of the drift is accentuated. This locality is on the divide between the Moravia-Freeville valley on the one hand and Fall Creek valley on the other; apparently ice-front waters had free drainage. These kame hills, therefore, have a topographical location that suggests quite a different genesis from the kame areas already described in, or adjacent to, valleys. Again, about one-half mile northeast of Morse Mill there is an extensive deposit of kame drift; and the water-laid moraine continues northward, but not so well developed, into the next sheet.

(6) *Eskers.* On this sheet two general types of eskers exist: (1) Those due to local topographic control; these are short, usually transverse to the direction of the valley axes, starting on one wall and terminating not far from the foot of the slope; (2) The other type appears to be less influenced by the minor details of relief. A full description of eskers appears in a later section.

(7) *Flood Plain Deposits.* These deposits are of two types: (1) Valley trains, the form developed in narrow valleys between morainal loops. In the valley of Fall Creek, and in a portion of the Moravia-Freeville valley, the valley trains attain typical development; they are discussed in detail later (p. 392). (2) Outwash plains noted especially at the wide triangular junction of two or more valleys where the several distributaries from the ice-front built up individual fans which coalesced into outwash plains. A few areas in the uplands have also been noted, bearing this same type of drift.

(8) *Lake Bottom Deposits.* The high-level lakes, held by the ice in the topographical basins of the sheet, are marked by a

veneer of lake sediments, which is not constant and its localization is somewhat puzzling. Two areas in particular may be mentioned: (1) The triangular section about Freeville; (2) The valley northwards from Locke and Moravia. The former of these has a topographic relationship that upon casual observation seems to offer no basin for enclosing a high-level lake. We recall the discussion of drainage lines in this area: Extending from Freeville toward Ithaca is the wide mature valley of Fall Creek, probably the oldest dissection line in the whole region. This valley, as pointed out by Tarr[14] hangs several hundred feet above Cayuga valley at Ithaca. The controlling ice lobe of the reg on was in Cayuga valley. During one of its retreatal stages, when perhaps its most distal reach was in the area of West Danby, several miles south of Ithaca, lateral tongues extended eastward into Sixmile creek, and Cascadilla valleys, while the eastern side of the lobe had a position northward from Turkey Hill (Dryden Quadrangle) blocking the wide flat-bottom valley of ancient[15] Fall Creek. The general northeast trend of the ice contemporaneous with this halt presumably marked an irregular line towards Cortland. It is felt, furthermore, that the valley tongue which for some time maintained a position at Groton (p. 357) may have been contemporaneous with the early period of this halt across Fall Creek valley in the vicinity of Varna. In connection with this discussion we need to note the possibility of southward overflow for this high level lake. The earliest static water about Freeville overflowed by way of the Dryden valley.[16] This stage was succeeded by others with spillways via Turkey hill, the details of which are given in a later section (p. 415). Even at the time of its highest outlet this lake was not deep. With the presence not far to the north, along the Freeville-Moravia and also along the valley about Cortland, of active ice, causing turbid water, which was the source of this clayish sediment, we have an explanation for the lake-bottom deposits noted in the vicinity of Freeville. The further fact that this clay deposit is more markedly developed in that portion of the triangular area towards Groton is in harmony with the hypothecated position of the ice; in the angle towards

[14] *Am. Geologist*, vol. xxxiii (1904), p. 273.

[15] F. Carney: "A Type Case in Diversion of Drainage," *Jour. of Geog.*, vol. ii (1903), pp. 115–24.

[16] T. L. Watson: *loc. cit.*, p. 292.

Fig. 16. Kame hills south of Benson Corners.

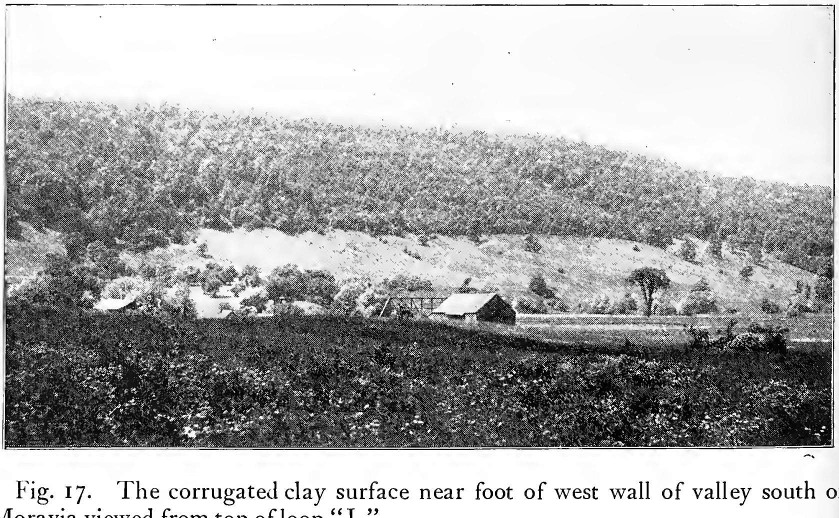


Fig. 17. The corrugated clay surface near foot of west wall of valley south of Moravia viewed from top of loop "I."

Cortland the development of clay is less conspicuous, as the area contains much outwash gravel which I describe in a later section.

The second area of these lake-bottom deposits is not so typical a case. The presence of clay south of Moravia has already been alluded to. While this clay may be interpreted as belonging to a temporary lake, nevertheless its deposition may be connected partially with a static body of long duration. The best illustration of it is found flanking the west wall of the valley near Moravia. Here the clays through slumping have assumed a corrugated form (fig. 17), mentioned in describing the drift of this region. Perhaps the case is not clear as to the controlling cause in this slumping. One would hardly expect such localization of lake clays as this area of slipping indicates. On the opposite side of the valley, however, the massive delta deposits (p. 410) indicate less quiet waters, as well as an additional source of the finer-textured sediments. While elsewhere in the valley only slight areas of this same clay have been noted, nevertheless I did not find such extensive deposits as would necessarily indicate a lake of long duration, carrying in suspension a marked amount of this clastic material; waters impounded along the valley tongue, or a stagnant portion of a valley tongue[17], may have afforded opportunity for its development. It should be remembered, however, that northward from the last moraine (p. 361) loop which is about a mile south of Moravia the valley-bottom obviously is the result of such deposition-work, both clastic and organic, as characterized the latest stages of the high level lakes.

It is felt that the study of these lake clays constitutes by itself a problem for investigation, and that the few facts here contributed barely touch the matter. The longitudinal valleys of Central New York each furnish more or less that should be studied and combined into a more detailed report on this topic.

DRIFT OF THE UPLANDS.

To draw a fast line between a region that would be classified as upland, and the valley area, is not easy. For the sake of discussion, however, we will take for the Moravia quadrangle the 1300-foot contour in general as the line of demarcation, along valley slopes, between upland and valley. On this premises the general

[17] Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), p. 99.

thickness of the upland drift as attested by 210 well records is 24.6 feet; and so far as 29 borings in the valleys give information the depth of drift in the latter area averages 112 feet. This latter measurement, however, has slight value since in these lowland areas water for domestic purposes is abundant at such slight depth that few deeper borings have been made.[18]

(1) *Ground Moraine.* Under this heading is included the glacial débris of irregular thickness covering the intervals between accumulations that mark more permanent halts of the ice. From a study of the areas over which the ground moraine is thinnest, it appears that the topography is an active factor in its distribution. Between the longer dissection axes of the localities where the drift is thin, and the direction of striæ is a pronounced parallelism.

This veneer of ground moraine presumably represents the load of rubbish carried by the ice that remained when the ice covering these areas, in no case very extensive, had become sluggish or stagnant, plus any sub-basal drift already accumulated. So long as active feeding persisted, the front of the ice probably maintained more or less fixed positions particularly in the region of lower altitudes, the valleys. It appears, therefore, that the normal outline of the ice-front in the Moravia quadrangle was serrate, the divide between the longitudinal valleys being ice-free while lobes and tongues occupied the intervening low areas. This ice-free condition of the higher regions probably followed a brief period during which stagnant or semi-inert ice covered the recently freed area. These were periods of less active feeding when the melting factor was much the stronger. The ground moraine consists largely of such a load of rubbish as this static ice contained. Where, however, in certain upland localities we find thickened drift, it is evident that the ice receded more slowly in consequence of much less inequality between the feeding and melting factors, the melting factor being slightly ascendant. In such areas it is apparent either that the ice retreated slowly, or that it contained a very large amount of rubbish. So far as the investigation has proceeded we have not been able to find in the topographic environment itself a plausible control for thickened drift of the uplands.

[18] The extremes for the well records below the 1300 contour are 45 feet and 300 feet 6 inches, neither of which reach rock; above this contour the extremes are zero and 135 feet.

Some quite extensive areas are particularly free of drift. These generally are regions of active ice erosion. One such locality exists south of Locke, commencing with the 1200-foot contour, and embracing a region of some five or six square miles northward of West Groton. The thin veneer of drift present consists of local stones embedded in an exceedingly slight amount of other drift. Some quite extensive plots are free of any drift, the local rock presenting a bare surface. Another similar locality is found southwest of Moravia, on the ascending slope which is reached by the first road running eastward from the valley. Here the horizon of very thin drift commences likewise at about the 1200-foot contour, and comprises three or four square miles. The description given for the area south of Locke is applicable to this region.

These two areas are typical of several others which are usually found on rock outliers, presenting a prow towards the northwest; in each case the longer axis of the fairly drift-free surface is quite parallel to the general direction of ice movement.

(2) *Terminal Moraines.* As the ice retreated across the Moravia quadrangle its front kept a general northeast-southwest position. The minor irregularities in its front gave rise to the several forms of valley drift discussed above. While the ice stood at a certain place in a valley, and drift was accumulating about the margin of the tongue, deposits were also forming away from the valley, thus registering the position of the ice in the uplands. If after the ice had kept a stationary front for some time, by feeding as fast as it wasted, there followed a period of much more rapid melting, thus causing the front to retreat rapidly, no pronounced accumulation of moraine would be formed; then if this period was succeeded by one in which the feeding and melting of the ice were about equal, thus depositing in a narrow strip all the débris carried by this wasted ice, we would have one more band of moraine. If, on the other hand, we do not have these alternating areas of thick and sparse drift, but instead an almost continuous heavy sheet of drift, which in fact is a wide moraine, we conclude that the ice wasted rapidly but fed on at but a slightly less rate; with such a relation the front of the ice receded slowly, and much débris accumulated.

The peculiar feature of the ice-front and the resulting arrangement of the drift in this quadrangle is its direction. The Cayuga

valley is wide and deep; for this reason a lobe of ice reached into this valley, extending far in advance of the front of the ice-sheet. But this valley itself is near the center of a greater basin, occupied by the Finger Lakes included between Otisco lake on the east and Canandaigua lake on the west. The effect of this Finger Lake basin on the general outline of the ice-front is well shown in Chamberlain's map of the terminal moraine of the "Second Glacial Epoch."[19] The proximity of such a deep valley just west of the Moravia sheet, and the fact that the southern half of this valley trends to the southeast, together with the fact that the sheet lies in the eastern half of the Finger Lake basin, accounts for the general northeast-southwest direction which the ice-front maintained as it gradually withdrew across the area.

While it is easy in the principal valleys of the sheet to map the longer halts of the ice as indicated by the loops, there was much uncertainty in definitely correlating the drift of the uplands with these loops. Two reasons particularly contribute to this condition: (1) The uplands contain irregular relief; in consequence the ice-front was also irregular, assuming new positions more frequently than in the valleys. (2) The work of marginal streams tended to blend the drift of these shorter halts. West of the Freeville-Moravia valley, there is slightly more system in the moraine; also in the southeast corner of the quadrangle distinct moraines were mapped.

In certain localities the moraine is characteristically developed. I will describe some of these, attempting at the same time to correlate them with general changes in the position of the ice; plate XII gives hypothetical chronological positions of this ice-margin. But the following discussion does not always consider the moraines in their supposed order of origin:

(*a*) The high points in the extreme southeast corner of the quadrangle were the first of the sheet to be ice-free. A beautifully developed moraine skirts these slopes. Between it and the westernmost of the hills the drainage from the ice-front escaped. In places this moraine is kame-like; one well gives a record of 70 feet mostly of gravel.

(*b*) Following this halt of the ice a second position is indicated by a belt of thickened drift commencing east of Mud Pond and

[19]U. S. Geol. Surv., *Third Annual Report* (1883), plate xxxiii.

ranging in altitude from 1240 to 1340 or 1350 feet. This moraine bears southward for a couple of miles and then directly south continuing along the hills east of Dryden in the Dryden quadrangle. In this distance its upper margin drops about 50 feet in altitude. In texture, so far as revealed in scattered sections, clay predominates, though areas of washed drift are not uncommon. The most marked development in this belt is attained nearer the edges of the quadrangle, the thinnest portions being found in the segment southeast of Malloryville. In the north part, or near Mud Pond, the belt blends with the kame deposits already referred to, the only distinction being in the texture of the materials; but southward there is no ambiguity as the drift both above and below the band is very thin.

(*c*) The great areas of kame moraine in the valley northeastward from Freeville probably indicate a slow retreat of the ice. A lake ponded in the Dryden valley reached into this area; the prevalence of the kame drift is partly due to this fact. East of McLean there is an extensive flat surface in the valley which suggests the burial of a stagnant mass of ice;[20] this mass was left as the high region just north appeared above the ice which afterwards fronted in Fall Creek valley. But south of McLean the retreat was gradual. At and west of Freeville there is a region of two or more square miles from which the ice appears to have withdrawn quickly; it is not improbable that a subdued moraine topography here may have been modified first by lake deposits and later by stream erosion. At any rate, in the valley itself, the first evidence of an ice-halt succeeding the loop south of the Junior Republic is one-half mile north of Freeville, where the slight development of the loop indicates a short halt.

From this time on till the glacier had disclosed about four-fifths of the sheet the line of its front trended southwestward. South of the parallel of Locke, the area between the Owasco Inlet and Fall Creek valleys is almost continuously buried by morainic drift from 20 to over 130 feet thick; there are three small outliers on which the drift is thin, but the surroundings are morainic. I was unable to definitely correlate much of this drift with halts in the valley south of Groton; the map gives one interpretation. But the Groton loop is part of a sharply developed

[20]Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), p. 98.

moraine which reaches across the sheet. Northwest of Groton this loop leads into a wide moraine the southern part of which may have been deposited when the ice extended a little farther south in the main valley; this drift blends continuously with deposits west and northwest. Where the highway leading east from West Groton crosses this drift it has a kame topography; for about a mile southward washed drift characterizes the belt. Crossing the slight valley of the brook which leads southeastward through Pleasant Valley to Peruville this moraine forms a low ridge or loop. Its continuation from this point is marked by the kame hills indicated in the irregularity of the 1400-foot contour line on the south wall of this valley.

At Benson Corners this moraine shows a variety of development. North and a little west of the Corners it assumes a ridge-like form, the axes having a northwest-southeast trend; while south of the Corners the drift has a typical kame aspect. This kame topography continues in a southeast band to the headwaters of Mill Creek, where a conspicuous ridge of drift crosses the valley indicating an earlier halt of the ice which is farther defined by the outwash gravel spread to the southeast; this ridge rises on the south wall of the valley to the 1280-foot contour, and the moraine, noted in line with a continuation of this ridge, crossing the higher area to the southwest, is another indication of this temporary position of the ice; drift of contemporaneous origin is found in the vicinity of the third south-leading highway, east of the southwest corner of the sheet.

It is apparent that this moraine is complex in development because the ice was gradually retreating with temporary halts. The two temporary halts already mentioned represent the protrusion of ice into low upland valleys, namely, Mill Creek valley and that of the Pleasant valley stream. These two variations indicate slight time periods, preceding the more permanent position which caused the major development of this moraine, which correlates more nearly with the Groton loop.

Returning, then, to the kame plexus south of Benson Corners, we note that this band of drift takes a direction to the southwest where it again has a very kame-like appearance (fig. 16), in the vicinity of the highway-crossing approximately one mile southwest of Benson Corners. Here the ice-front held an east-west course for about one-half a mile, continuing thence in a line

approximately south-20°-west. The drift ridge which marks the latter position is followed by a highway, the second north-south road east of Asbury; it is also indicated by the contour line. This moraine continues in the general direction already mentioned southward leaving the sheet. The sharpest development of the ridge is in the valley east of Asbury; nevertheless the line of drift may be traced southward up over the rock salient, which has an altitude of 1120 feet, thence down the south slope of this hill, where the drift becomes more kame-like and blends into the accumulations of the Dryden sheet.

The ice apparently kept this general position for a time after the valley tongue had withdrawn from Groton, for this moraine continues, when traced northward, into Cayuga county, blending with valley drift west of loop "F" (p. 358).

I would allude again to the fact that this moraine shows clearly the control exercised by the Cayuga valley lobe on the ice-front in this part of the Moravia quadrangle. The irregular course of the drift belt is not so perplexing when we consider the topography of the Genoa sheet in connection with that of the Moravia quadrangle. This is further evidence that the particular form assumed by the margin of a receding continental glacier reflects the local topography to a much greater extent than the general topography of the area farther northward.

The eastern segment of the Groton loop continues northward; but the whole region east and northeast of Groton is such a morainic complex[21] it is quite impossible to map particular halts except where a minor protuberance of the ice has stood across one of the upland valleys from which it retreated rapidly, as south of Summer Hill, and again west of this place. The greatest established depth of this drift is 135 feet, a well record on the Summer Hill road at the farm of A. C. Ranny, and this well does not reach rock; directly south of this well, on the next road, rock was reached at 85 feet. The last position of the glacier associated with the moraine under consideration is indicated by a band of drift, in places one-half mile wide, extending to North Summer Hill where a stationary position of the ice-front is indicated by both the heavy hummocky moraine and the drift loop.

Eastward, the ice reached south in crossing the lower area about Lake Como; a very distinct terminal moraine was developed

[21] Tarr: *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 223.

contemporaneous with part of the moraine discussed above; this will be described next.

(*d*) Extending northward from the vicinity of Como the 1700-foot contour marks the general course of another of these distinct bands of drift. The arrangement of the moraine east of Como has already been referred to in connection with the valley deposits; the valley east of Como contains much drift. Its association with the moraine northward is not entirely clear, though it seems evident that part at least of the drift in this short valley is contemporaneous in origin, i.e., that for a few miles here the front of the ice was nearly north-south. The hill just northeast of Como, which reaches an altitude of 1700 feet, is in the main drift-covered, part of which is elsewhere described as nunatak deposit (p. 388), an explanation not essentially at variance with moraine interpretation of the drift to the northward; I have frequently noted evidence of these briefer positions of the ice preceding a longer halt. Near the ice-front channel leading into Skaneateles Inlet valley this drift assumes a rather kame-like phase; in this northern portion the heavy part of the moraine is rather narrow and thins both up and down the slope. Along a line paralleled by the highway southward from the entrance to the Skaneateles overflow channel the drift again thickens; it is probable that this represents another halt of the ice following a short period of greater melting or of less activity.

Between this valley and the Dresserville valley is a long divide, rising more than 300 feet above either valley. That the ice moved from the west across this high ridge is shown by the arrangement of the moraine just described. On the west slope of the valley extending north from Como there is very little drift, while moraine is sharply developed on the opposite slope. At the northern end of the valley there is evidence that at a later stage a slight tongue of ice reached a short distance southward.

Contemporaneous with the development of this moraine a dependency from the ice-sheet reached south into the Skaneateles Inlet valley even beyond the margin of the Moravia sheet.

(*e*) Morse Mill and Sempronius lie within an east-west belt of moraine. In mapping the deposits of this area I have appreciated the influence of the Skaneateles Inlet valley, and of the valley between Morse Mill and Dresserville. The proximity of these valleys would tend to increase the development of drift through-

out the intervening divide. The fact, however, that this general development of the drift covers not only the portion of the quadrangle north of Sempronius but reaches also into the adjacent parts of the Skaneateles quadrangle is evidence of a continuous hesitancy in the withdrawal of the ice. Furthermore, even in the most elevated parts of this region, as the hill northeast of Sempronius which reaches an altitude of nearly 1800 feet, the drift is thick and shows a normal morainal-surface development. In these same high levels, the bowlders are large and numerous. It is inferred, therefore, that the ice maintained an east-west frontal position in this part of the quadrangle for quite a long time.

(*f*) The portion of the quadrangle west of the Moravia-Locke valley and north of the tributary rising near North Lansing has a deep covering of drift; only a small part of this is associated with a tongue of ice extending southward into the Moravia valley. From the vicinity of the Owasco Hill to the valley of Hollow Brook is a band of thickened drift, the general position of which is marked by the 1400-foot contour; but towards the southern extremity, the band grows broader and reaches even below the 1300-foot contour. It is clear that the line of drift thus defined is all of the same origin. At the north end, the belt blends into an extensive plexus of drift knolls and ridges that continue along this west slope of the Owasco valley reaching into the quadrangle to the north; at its southern end, it blends into extensive accumulations that encompass both walls of the Hollow Brook valley, being continuous even with the drift which has a marked development at Goose Tree and westward. But the continuity of the belt within these limits points to a relatively permanent position of the ice-front throughout much time. Washed deposits in the form of knolls characterize the whole length of this moraine. In this connection it may be noted that free ice-front drainage probably existed southward through the valley opening out in the vicinity of Locke. This moraine does not admit of definite analysis into positions correlating with the halts in the valley east of it. The longest halt in this upland district is indicated by the moraine which the 1400-foot contour follows southward for about three miles. It is clear that the ice receded very slowly and that it was well burdened with débris. The loops of drift in the valley north of Locke were found to be poorly developed on their western sides when attempt was made to trace them into the moraine just described.

(*g*) Including some six miles along the western side of the sheet, from North Lansing as far north as the headwater area of Hollow Brook, the moraine is so strong as to suggest a permanent position of ice-front. But its development may be completely interpreted only in connection with the adjacent drift of the Genoa quadrangle. It is probable that by the time this moraine was being deposited, the eastern side of the Cayuga lobe had commenced to develop an irregularity due to Salmon Creek valley. The southern portion of this drift area is alluded to in the preceding section as continuous with morainal development about Goose Tree. The abundance of washed deposits over an area a mile square, north and east of North Lansing, is in keeping with the topography and the relations that the ice-front evidently maintained to this general southward rock slope.

(3) *Nunatak Drift.* The maximum thickness of the great ice sheet was attained far from its outer margin. Various estimates[22] have been made of its depth at several points in northeastern North America. Whatever may have been the depth of ice in any particular locality, it is evident that towards the outer edge the ice sheet tapered to the uncovered region. The condition must have been analagous to the relations of the ice noted now in Greenland where there is a seaward thinning.

The irregular topography, the result of a complex drainage history, would give the decaying ice a more or less patchy surface condition. As the ice grew thinner the highest land areas, if limited in extent, evidently would show through the sheet, presenting bare surfaces designated nunataks, or limited ice-free areas sometimes surrounded entirely, and again partly surrounded by the glacier. It is obvious that when such a point of land has appeared above the sheet, melting in its immediate neighborhood would be increased because of the heat reflected from the bare rock or soil.

So long then as the ice continued in this position in reference to the nunatak, a quantity of glacial débris would be accumulated. The decay of the ice evidently was more rapid on the southern exposure of the nunatak; the fact that the glacier in general fed from the north would accentuate this difference in the height of the ice about the exposed hill. There would be a tendency for drainage to carry more or less drift, other things being equal, to

[22] Chamberlin & Salisbury: *Geol.*, vol. iii (1906), pp. 355–58.

the leeward side of the nunatak. On the other hand, superglacial, and perhaps in some cases subglacial, drainage accounts for the accumulation of washed material on the stoss side of some nunataks. It has been noted, furthermore, that the drift development in all cases in the area studied is more pronounced on the west and southern exposures of nunataks.

The nunataks from which the preceding general deductions have been made are grouped as follows: (*a*) In the southeastern part of the quadrangle a hill rises to an altitude of 1810 feet. A study of the slopes of this hill shows on its southern side a quantity of drift which extends usually below the 1700-foot contour. Elsewhere about the hill there is slight evidence of its having continued very long as a nunatak. The general relationship of this hill to the topography to the east and to the south appears to preclude any protracted nunatak period. After the ice sheet had thinned to the level of this nunatak further decay shortly brought above the ice surface, if not beyond its front, the whole region of which this hill is a part.

(*b*) About a mile northwest of the above area is a fairly isolated hill reaching an altitude of 1600 feet. The evidence of drift on the flanks of this slope is more pronounced than in the preceding case. A variation, however, should be noted here, since the association of drift in the region immediately south, where the slope drops down to the 1400-foot contour, suggests that a small tongue of ice may have continued in the area after the nunatak phase of this hill had ceased to exist. The kame and kettle development between the 1500-foot contour and the top of the hill on its southern slope therefore may not be entirely of nunatak origin. Nevertheless, such accumulation of washed drift on the southern slopes of nunataks is normal, especially where the body of water in which apparently the deposit was made endured for some time. The ultimate outlet of the water that gathered in the area under consideration, an ice-walled channel, is indicated by the rock cliff and terrace parallel to the highway leading southwest along the hill directly west of the nunatak described under (*a*). The base of this cliff is approximately 1500 feet and its upper limit cannot be definitely defined now because of post-glacial weathering. In any event the evidence of a slight body of water held up in this basin between the high areas discussed in this and the preceding paragraph is conclusive.

(*c*) Northeast of Como, a hill, which appears to be an outlier of the higher ground still father northeast, reaches an altitude of 1700 feet. The unusual association of drift on the flanks and on the southern end of this hill attracts attention; its western slope bears a collar of drift, using a term coined by Tarr,[23] while the southern extremity of the nunatak bears several knolls of washed material. This association is not a definite case of nunatak deposit for the reason that the area is so intimately connected with the moraine extending northward, already described (p. 386), that the typical conditions for a nunatak may be questioned. It is clear, however, that the topography exercised an active control on the drift in question.

(*d*) Just north of the ice-front channel which leads into the Skaneateles Inlet valley, is a hill 1720 feet in altitude. The topographic relationship here favored the appearance of a nunatak, and the mapping of the drift about this hill proves that the nunatak phase was not of temporary duration. In the Skaneateles valley to the eastward a tongue of ice was present sometime after the general ice-front had retreated northward. With the thinning of the sheet conditions favored a depth of ice to the east for some period of time during which the exposed hill maintained a nunatak relationship. Here, to a degree not noted elsewhere on the quadrangle, the collar moraine is developed. The prow or stoss end of the nunatak bears an accumulation of small kames, while the leeward slope is covered likewise by knolls of washed drift. It should be stated that on all sides of this nunatak, save the west, the deposits are sharply demarcated from the slopes that are practically drift-free. Towards the west, however, the control exercised by the Fall Creek valley has resulted in a continuous development of moraine in which it appears that the drift of nunatak is not differentiated from the drift of the lateral moraine type.

(*e*) Southwest of Moravia, Jewett's hill, which reaches an altitude of 1448 feet, apparently bore a brief nunatak relationship to the ice-sheet. Where the highway, ascending the slope from the north, turns directly to the west, a band of thickened drift is apparent on the surface, and is proved by well records. The other slopes of the hill do not seem to have witnessed the accumu-

[23] *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 225.

lation of much glacial débris. An obvious reason for this, perhaps, is the temporary position of the ice, as well as the gradual slope of the area to the west.

(*f*) At several other points throughout the quadrangle, one notes in the uplands localizations of drift, more or less kamy in texture, that suggest nunatak relationships. The cases are not always clear enough to warrant this explanation of the deposits. Two localities may be mentioned as typical of these: (1) At Fitts Corners is a pronounced kame area, alluded to in the discussion of kames (p. 376). Bearing in mind the relationship of this region to Fall Creek valley, and noting the topography to the north, there is a suggestion of conditions that probably produced, for a temporary period, stagnant ice to the south, while there existed an ice-free area just northward. The Fitts Corners locality is not sufficiently isolated to warrant the name nunatak; nevertheless the probable persistence of ice about the region afforded the environment that governs the formation of nunatak drift. (2) A further illustration of these areas is the height of land surrounded by the 1700-foot contour southeast of Lickville. The irregularity of this contour, particularly on the north, marks a drift-collar, representing a temporary exposure of this area, while all the adjacent region was beneath the ice.

Parallel Ridges of Drift. In three localities on the sheet I have mapped an unusual parallelism of drift ridges. The most pronounced development was noted east of the highway that extends northwest from Owasco Hill; the ridges here are 10 to 40 rods in length, 15 to 25 feet high, and from surface appearance contain much washed material.

One-half mile north from Lafayette a highway leads east; near the margin of the sheet, and some 80 rods north of this road is another series of these ridges; here, however, unmodified drift is more abundant than in the former locality, but good sections are wanting. In neither case is the characterization as to content very accurate.

A short distance north and west of Benson Corners are several ridges, somewhat parallel, but much broader and less sharply defined than in the two areas already mentioned. The material of these ridges is prevailingly fine, from surface indications. Some have a tendency to broaden and flatten towards the northwest.

The ridges of the first area referred to appear to be constructional in origin; their direction marks the lateral margin of the declining Owasco lobe. This genesis seems less applicable to the ridges of the second locality; here conditions favored stream erosion which may have been a factor. The Benson Corners area apparently represents initially the drift that accumulated in the reëntrant angles where the ice-margin had locally assumed a serrate outline; erosion has later altered these deposits, flattening them in the direction of the slope, i. e., to the northwest.

Valley Trains and Outwash Plains.

Both these forms of drift have to do quite as much with topographical relationships as with the positions of ice halts. In a longitudinal valley having so constant a slope to the north that a continuous ice-dammed lake is held up as the ice tongue recedes, we will not find illustrations of the typical valley train. This form of drift develops best in valleys having a slope away from the ice-front; but an initial iceward slope of the valley may be reversed by the gradual filling of the lake from the ice-contact end. With this topographic condition, then each loop of drift may connect southward with a valley train. In any event there is bound to be some distribution of drift away from the loop, which marks the position of the ice, even when a static body of water rests against the loop being formed. In this case the plain of more or less modified drift will be shorter and evidently also steeper in slope since it will represent the deposition of material held in suspension by the water; and with a continuance of these deposits the grade in this part of the valley would at length be changed, and outwash material be built up normally. A section of deposits made under these conditions would show clay at the bottom grading upward into gravel.

It is observed that Fall Creek valley from lake Como southward offers the only area for the normal development of valley trains. Since the development attained by a valley train is intimately connected with the development of the moraine loop with which it is associated, it follows that we have the most pronounced trains only where the loops are conspicuous. In Fall Creek valley the particular halts of the ice, with one exception, appear to have been brief. The Como halt is characterized by a marked

silting up of the valley floor. To a less extent this is true of a halt immediately south.

In the Moravia-Freeville valley, where we find the best developed valley loops of the sheet, the northward slope that the valley floor has, as explained above, hindered the formation of typical valley trains. In this connection, however, it should be remembered that a valley train having undergone rather active erosion in post-Wisconsin times is apt to be so altered as to lose its more definite aspects. This valley has been subject to erosion by a north-flowing stream during part of the post-Wisconsin interval or at least since the high-level lake in it fell below the Lansing outlet; the present stream here drops 325 feet in 12 miles, a grade of 27 feet per mile.

The level area, which is quite extensive for some distance south of Moravia, is partially the product of delta filling that has constantly followed the receding lake level, and is still in progress just north of this sheet. Another interval of fairly level bottom, just south, cannot with certainty be explained as entirely of valley-train genesis. From Peruville southward, however, where the old valley floor doubtless has a southern slope, we may recognize the play of ice-front streams aggrading to the extent of producing valley trains. This suggestion pertains especially to the ice-front drainage characterizing the halt at Peruville.

The normal conditions for the formation of outwash plains, as described by Salisbury,[24] do not exist on the Moravia sheet. Nevertheless there is evidence particularly in the vicinity of Freeville where we have a very broad valley bottom, broader still no doubt before the kame deposits were made eastward by the retreating Wisconsin ice, of the conditions which here favor the coalescence of alluvial fans of ice-stream origin. The great masses of kame moraine flanking the Freeville-Cortland valley represent a duration of ice-débris accumulation that must have been attended by heavily burdened streams flowing away from the Freeville area. The Junior Republic kames, however, were formed when the ice obstructed the drainage, thus ponding a lake which extended southward overflowing south of Dryden lake; so long as ice blocked the ponded water from escaping westward through Fall Creek valley, outwash gravels developed only as fans into

[24] *Geol. Surv. of New Jersey*, vol. v (1902), pp. 128–9.

the static water. Succeeding this lake stage the heavy ice-front drainage spread gravels southward from the vicinity of Red Mill, and in the valley east of the Junior Republic kame area.

Eskers.

As already noted the eskers of this sheet appear to fall into two general classes, (1) those that are connected with local topography, and (2) those more or less independent of the details of topography. There follows a description of the general characteristics of each of the several eskers on the sheet; their location may be found on plate XII, which also indicates by arrow the supposed direction of the esker stream.

No. 1. This esker originates a short distance southwest of West Dryden. The altitude of this area is about 1200 feet, and the drift, which is rather well developed in the vicinity of this village, attains considerable thickness, one dug well having reached a depth of forty feet without encountering rock; the texture of the material as revealed by this well indicates emphatically a washed-deposit origin; the stones contained in it are generally smooth, and there is considerable sand present. So we have in drift topography about West Dryden a suggestion of conditions that govern kame accumulation.

This esker measures on the Moravia sheet but three-eighths of a mile. Its general direction is south approximately 10° west, and this course continues for some distance on the Dryden sheet, then it turns more to the east. The northern segment of the esker, or that on the Moravia quadrangle, so far as revealed by one section and by surface appearance abounds in finer material. There is no evidence of more than a small amount of coarser stones either on the esker or in its environing drift.

No. 2. This esker has its origin apparently at the first four corners east of West Dryden. For one-half mile its course is due southeast, parallel to the brook that flows towards Fall creek. Then it takes a more easterly course. Farm buildings mark its intersection with the next highway to the east. A few rods beyond this road the esker divides, one branch bearing north and east, while the other takes a southern course passing out of Moravia into the Dryden sheet. The vertical range of this esker is about 140 feet, having a continuous decline.

Between the first mentioned highways the esker attains a sharp and typical development. No other on the sheet displays such a continuity of even meanders; but from the point of division the ridges are lower and more flattened. The eastern of these two divisions breaks up shortly into distributaries which lead into a low flat area of sandy soil, the development of which is hardly ample to warrant the designation "sand plain." While the division turning south is typically developed in a few segments, in the main its appearance is indicative of a subglacial stream which had already disposed of most of its load.

As indicated above, the first half-mile of the esker is without a break. The brook which it parallels, however, then cuts across the esker, taking advantage evidently of a low place in the ridge. Just before reaching this breach in the ridge, in walking along the esker from the northeast, one observes on the west side a tributary ridge not many rods long but attaining considerable height near the place of junction with the main esker. So far as may be determined from the surface, in the absence of fresh sections, the material of this esker is prevailingly fine.

No. 3 (fig. 18). There is considerable obscurity as to the termini of this esker. Kame moraine practically hems the esker in except for a portion of its southern side, and either end of the esker appears to be buried or to be interfered with by the agencies connected genetically with this marked kame development.

The ridge in places approximates fifty feet in altitude, and has steep slopes. Some complexity of the subglacial drainage here is suggested by a tributary ridge from the south towards the eastern end of the esker. As exposed in the railroad cut the esker is rather coarse in structure, indicating the vigor of the subglacial stream. It is felt that in an esker of the proportions evidenced by this there should be a typical development of sand plain. The fact, however, that in all parts of the valley, save where the kame topography abounds, outwash material has leveled up to some extent the natural inequalities tends to obliterate the sand plain structure that may have existed; furthermore this absence of the finer assorted deposits that would indicate a static body of water is evidence that when the esker stream was active the front of the ice had retreated, allowing the drainage of Dryden valley to flow westward, thus terminating the lake stage.

A feature worthy of note in connection with this esker is the

long kettle hole immediately north, mapped on the topographic sheet. It may be stated also that this is the only esker on the quadrangle which is denoted by the contours.

No. 4. The highway leading north from Jones Corners intercepts a brook just before the first road-crossing. Commencing a few rods east of this highway an esker extends down the slope of the valley for about one-fourth of a mile. No development of the ridge was noted to the west of the highway. Since the

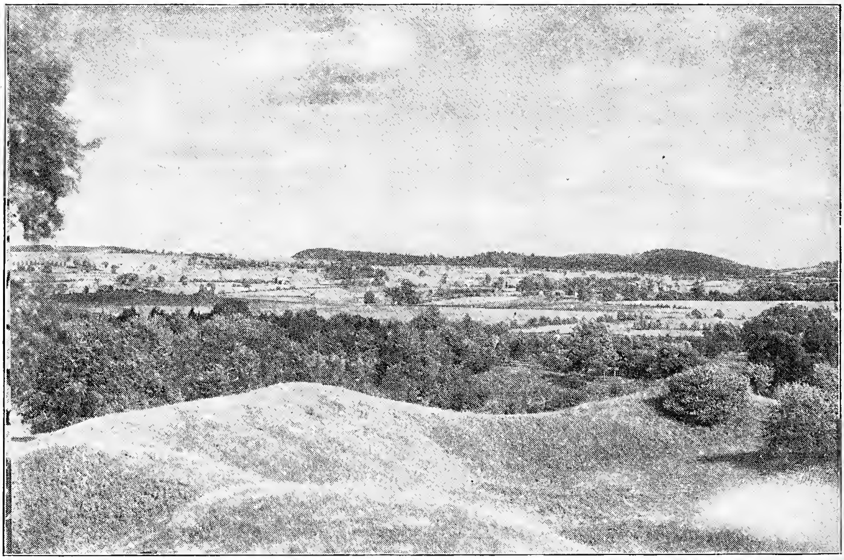


Fig. 18. Esker No. 4. The entire sky-line is the eastern rock wall of Fall Creek valley; the sag near the left is a marked kame area. The camera points a little north of a line normal to the axis of this glacially aggraded valley.

direction of this esker is longitudinal to the valley, we would anticipate a greater length. The grade of course favors pronounced flow of the subglacial stream. Where the esker ridge becomes discontinuous the valley moraine is well develo ed. This fact suggests the possible deformation of the esker ridge by the ice-front deposits. Certain drift accumulations, ridge-like in form, have been mapped as possibly disconnected segments of the original esker. About halfway down this valley an abandoned lime kiln stands on one such segment. About the surface of both

the moraine swells and the esker itself, bowlders are numerous. This is the only one of the four eskers already considered that bears a conspicuous development of bowlders.

No. 5. East of Lafayette is a valley opening northward. The last half mile of this valley before it joins the Fall Creek valley carries an esker, the northern portion of which has attained a very typical development. The esker in the distance over which it has been mapped has an unbroken vertical range of about 120 feet. At the point where the valley widens rapidly the esker swings towards the eastern wall which it skirts for a short distance before it turns to the west into the flood plain section. The valley to the east and south, it was thought, ought to give some evidence of an extension of the esker in that direction; but no ridge exists there. About one-half mile to the southeast is a marked development of low kames probably associated with the esker. Just west of this kame area is an ice-front drainage channel, the stream of which may have removed a portion of the esker.

Northwest, in the flood plain of Fall Creek valley, and in line with the ridge above described, is another gravel ridge which I at first mapped as a separate esker. Its best development is noted near its western terminus where it is about 19 feet high, and its side walls slope 24°. Furthermore, its development here is very symmetrical. To the east, however, it gradually flattens, terminating in low kame knolls. The original development of both the esker and the low knolls of washed material has been somewhat obscured by the great quantity of outwash deposits that are graded down the Fall Creek valley. It is probable that these disconnected ridges belong to the same subglacial stream, and that the gap may be due to both an incomplete initial development and a later partial removal by ice-front stream erosion.

No. 6. An esker, that has a beautifully meandering course, may be seen a short distance south and east of Rogers Corners. This ridge is approximately one-half a mile long. Its southern end has been modified considerably by drainage-dissection, as it reaches to the axis and probably formerly beyond the axis of Fall Creek valley. There is a faint suggestion towards the bottom of the valley of two distributaries though the case is not clear in the presence of alterations or obscurity through outwash deposits. The ridge attains nowhere a height of more than twelve to fifteen feet, and its side walls slope gently. Furthermore in its texture fine material predominates.

No. 7. This esker has its origin on the steep slope south and east of Como. Its vertical range is little more than 100 feet, but its length is scarcely one-eighth of a mile; the esker attains a stout development even in this short distance. Kame deposits are plentiful about the slopes of the hill to the north, and the esker material too consists largely of washed deposits. From the height of the esker and the slopes of its flanks it seems natural that formerly it had a greater linear extent. Just north of this location are accumulations which reach across the valley; the ice fronted along the line of these kames, and the drainage tended to work over the drift deposits immediately southward in the valley. Therefore the wide area of washed drift which now extends southward in the line of this esker has probably obscured, and degraded portions of the ridge. A couple of isolated hills of drift near the middle of the valley, it was noted, are in line with this esker and add to the pertinency of the suggestion.

No. 8. Of the eskers studied on the sheet this had attained the greatest development. The termini of the segments which it is thought represent the original esker give it a distance of approximately five miles. In several places the ridge is completely wanting, one gap at least being normal; this is where post-glacial drainage has cut the ridge.

Faint suggestions of subglacial stream deposits are noted at and slightly above the 1600-foot contour a little northeast of North Summer Hill; a plexus of drift knolls containing a large percentage of washed material exists in this same locality. I am not satisfied that there is any genetic association, however, between this accumulation and the esker. The fact that a gap several rods long occurs immediately to the southwest is the most serious objection to any such association. Where the map next indicates a development of the esker, the ridge is clear and in all respects normal. Then follows a short break, but with enough localizing of drift to warrant making the ridge continuous. From this point on, however, to the last interruption at about the 1600-foot contour southwest, the ridge is strongly and normally developed.

Continuing southwest from the gap in the esker occasioned by the intersection of Dry Run, we find about the 1480-foot contour the same marked development of the winding ridge. After crossing the next highway the esker locally expands into a kame cluster; narrowing down again it continues to the top of the grade where

the ridge flattens and becomes rather indefinite; but to the west of the next public road we come to an elongated ridge that appears to split into two distributaries, both of which turn rather sharply to the south. That these ridges are genetically associated with the esker does not seem proved especially since their continuation north or east is so indefinite. Were the ridges differently oriented we would scarcely consider their association with a subglacial stream, but the direction they take from a line which is continuous with the esker would seem to indicate the influence of more active ice in the Locke valley deflecting the esker stream southward as these ridges point.

In this connection reference may well be made to a geographic influence illustrated particularly in this esker as well as in some of the others. I refer to the location of farm buildings at the intersection of highways with this ridge of drift. Commencing at its supposed point of origin it is noted that every highway crossing save the last to the extreme southwest has been made the location of farm buildings.

No. 9. This esker lies directly north of the southern portion of No. 8. Locally it is referred to by the farmer as the "Indian Road," and the older residents have a legend as to this turnpike of drift having been constructed by the red men. The ridge is indeed scarcely higher than a well made pike, and its course through a swamp area about a half-mile wide is very suggestive of artificial origin. The topographic map makes the slope occupied by this esker much steeper than it really is. As a matter of fact in its whole distance the esker descends northward less than thirty feet, whereas by the mapping it should drop one hundred. The swamp appears to be the result purely of undeveloped drainage lines, as it occupies a flat elevated area including perhaps a square mile. It has been heavily forested, and in lumbering operations the esker is used as a highway.

No sections are present, but judging from the surface it is inferred that the esker material is coarse; in some places the presence of till was noted. No characteristic terminal phenomena were observed; the ridge begins and ends almost imperceptibly. While its course is not straight, nevertheless the curves are few and long.

GENERAL DISCUSSION OF ESKERS.

Location. From the standpoint of altitude we note that Nos. 2 and 3 start below the 1200-foot contour. All the others are higher. Nos. 1 to 4, 6 and 7, descend with the valley wall on which they lie, and terminate, so far as has been observed for those wholly on the Moravia quadrangle, in the flat valley bottoms. No. 5 starts on a flood plain and ascends over 100 feet. No. 9 reaches across a level upland swamp. No. 8, transverse to drainage slopes, is highest in altitude and exhibits the greatest vertical range.

Direction. Nos. 1, 2, 3 and 5 are more or less in harmony with the supposed movement of the ice. No. 9 appears to be opposed to ice movement, while No. 8 is plainly transverse, and Nos. 4, 6 and 7 are somewhat transverse to the line of ice motion. No. 8 exhibits a possible yielding to the activity of the moving ice; by reference to the map we observe that this esker crosses a well developed drainage line which opens toward the general direction of ice motion. The segment of the esker as it crosses the axis of this valley obviously bows in the direction of ice motion. For this reason it is felt that the subglacial stream developed the course indicated by the esker ridge.

Genesis. It is already apparent from this discussion that we are dealing with two types of conditions from which corresponding types of eskers have taken their origin. Nos. 4, 6, 7 and 9, all of which are short and occupy each a continuous slope, evidently were produced in a brief space of time. They represent the transient drainage that became subglacial from a superglacial position, or from marginal areas of ponded water adjacent to stagnant ice which occupied the neighboring low areas, being merely a line of escape of such waters. The conditions are not identical in all of these, but they have in common the location in reference to a valley, and the short linear extension indicating a brief period of formation.

No. 7 originates in a cluster of kame knolls indicating clearly the subglacial course of waters formerly superglacial or marginal. If the point at which this drainage became subglacial had been 40 or 50 rods to the east the course of the resulting esker would have been either south or southeast. The position of the kame deposits in the vicinty of Lake Como is evidence that a large area

of ice extending eastward into the tributary valley became stagnant here. Before the mass of ice had thinned down to a level where "ablation moraine"[25] might gather, thus protecting it from speedy decay, drainage lines were developed beneath it, particularly from the point where marginal or superglacial streams gave a head to the water. Consequently this esker resulted from the escape of water confined between the ice and the high ground to the north and east. The eastward extending tongue of ice here formed a barrier which in connection with the ice in the Fall Creek valley adjacent held up the drainage gathering from the north as well as that coming from the decaying ice. The only outlet for these waters was around the end of the ice tongue, a course which the drainage for some time did take, but as the ice became more and more stagnant the subglacial course was developed. Furthermore, the material of this esker is prevailingly fine, indicating that the chief source of supply was found in the kames where it originates.

While No. 4 is plainly also the result of a gravitative direction given to drainage, the further point of variation in texture indicates different conditions than obtain in No. 7. Here we have no feeding kame area; we have a strong suggestion of coarse till-like material in the esker. Throughout its length, so far as may be mapped with certainty, there is a slight fall, which may account partly for the absence of washed material. Terminally the esker is without characteristic features.

By consulting the topographic map we note that the topography in the vicinity of esker No. 9 favored the development of a reentrant angle of ice-free surface. Thus the ice here formed a saddle; in the sag between it and the rising land south water accumulated. Judging from the present contours, and granting the most favorable condition of this interpretation, such a body of water had slight areal extent and apparently during most of its period did not have a depth of more than twenty feet; but as the ice decayed, it became somewhat larger and deeper. If a stagnant condition of the ice existed for but a short time we may understand how this water found a sub-ice outlet, associated probably with a subglacial stream already flowing southward along the east wall of the valley towards Locke. The slight development of this esker indicates the short duration of the stream.

[25] Tarr: *Zeitschrift für Gletscherkunde*, band iii (1908), pp. 85–88.

Vertical Range. The gradient of an esker-forming stream probably is represented by the vertical range of the esker. In the following data the figures enclosed in parentheses represent the gradient in feet per mile of the esker stream: The range in altitude of esker No. 1 is 100 feet (160 feet); of No. 2, 140 feet (82 feet); of No. 3, 80 feet (80 feet); of No. 4, if we consider only the unbroken segment, 15 feet (60 feet), but considering the scattered segments of the possible former esker the gradient is much sharper, as it trends eastward down the slope; of No. 5, 100 feet (100 feet); of No. 6, 160 feet (320 feet); of No. 7, 70 feet (263 feet); of No. 8 the gradient is broken since it crosses in its length of four and one-half or five miles, one marked valley and one valley of lesser development. The northern segment of this esker drops about 200 feet. Even this distance, however, is broken by the

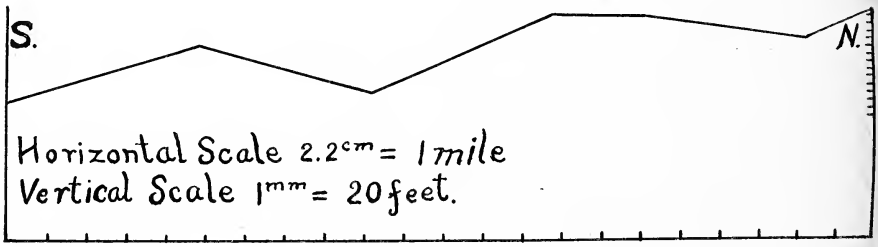


Fig. 19. A profile showing the broken gradient of Esker No. 8.

lesser valley just alluded to. The portion south of Dry Run rises about 120 feet. Fig. 19 plots the grade of this esker stream. The vertical range of esker No. 9 is about 30 feet (46 feet).

From these figures, and the description of the eskers given in the preceding sections, it is apparent that streams of sharp gradient did not develop the highest esker ridges. The low eskers as well as the ridges having low lateral slopes have the higher range in altitude. No. 7, however, appears to be an exception, but as already explained, the lower course of this esker has probably been so altered by outwash material and ice-front streams that the remnant represents but a fraction of the original development, and this remaining portion is the upstream end which has the sharpest gradient; the hypothecated removed segment had a lower gradient. On the other hand, eskers Nos. 4 and 9 have both a

low gradient and a low ridge. The material constituting these two eskers contains a preponderance of coarse deposits; and the former, much till. This prevalence of unmodified drift suggests slight water action.

Esker No. 2 illustrates best of any the typical serpentine course which characterizes the paths of some subglacial streams. The meandering form is also excellently shown in portions of Nos. 3 and 8. It is not well developed in eskers having either the lowest or the highest gradients. A great bulk of aggraded material, it is observed, is present where the sinuous course has a sustained development. Since the esker ridge is developed beneath the ice, the ice-cave being enlarged by ablation as the stream becomes more and more aggraded, the question arises as to the development of meanders. To what extent do the principles accepted as governing meander belts in subaërial streams obtain in the evolution of the sinuous esker ridges? It is very certain that a low stream-gradient does not account for the meanderings of the esker ridges discussed above. I do not believe the meandering of subaërial streams is induced entirely by a sluggish flow.

Ice Motion. The location, direction and degree of development of these eskers, with probably one exception, indicate genetic association with stagnant ice. Nos. 1, 2 and 3 are probably contemporaneous in formation and indicate the interval of inactivity that followed the halt associated with the valley loop south of Freeville. Nos. 4 to 7, which were formed somewhat in the order named, have their genesis with the decaying lobe that reached southward through the Fall Creek valley. That none of these eskers attained a very marked development is due doubtless to the rapid decaying of this inactive ice. Esker No. 9 likewise represents the brief duration of a subglacial stream; the esker ridge is low, and its material, as already mentioned, contains a large amount of coarse ingredients, both characteristics indicating an inactive flow of water.

The only esker on the sheet that suggests a genesis not immediately governed by the underlying topography is No. 8. This ridge represents furthermore a considerable activity of the ice; brief mention has already been made of this fact. The middle portion of its course, which is convex to the southeast, is supposed to be normal to a line of the more vigorous ice which occupied the trough of Dry Run. It is supposed that the whole region was

then covered with ice, and that the subglacial stream had its course marked out shortly preceding the period of subdued activity when the ice on the higher areas to the south and southeast disappeared completely. The manner in which the southwest portion of this esker shows some southward deflection seems also to indicate the activity of the ice still remaining in the Moravia valley.

Conclusion. (*a*) As to distribution, these eskers illustrate the usual association between slopes and streams. Nos. 2, 4 and the southern part of No. 5 are quite parallel to the axis of the valley which each follows. Nos. 1, 3, 6, 7 and 9 course down valley walls of moderate slopes. In the case of No. 3, however, the valley-wall control is not so obvious. This esker probably trends north of the course which the rock slope, here deeply buried, would give it.

(*b*) In reference to degree of development, those eskers having the slightest gradients are most pronounced, both in bulk of deposits and in sinuosity of course.

(*c*) As to cause, it is apparent that the eskers of this sheet are due to an association of inactive ice and relief. In the absence of valleys and plains of marked gradient, eskers would be much less common, as they would then represent the subglacial outlets of superglacial waterways. Stagnant, or slightly active, ice appears to have been the principal factor associated with the eskers of the Moravia quadrangle.

Bowlders of the Drift.

Composition. The most conspicuous of the glacial bowlders seen in the Moravia quadrangle consist of crystalline rocks carried in from the Canadian or other northern areas. Bowlders of local and neighboring sedimentary rocks were likewise noted. On the west wall of the valley just south of the moraine loop "F" (p. 358), many Oriskany sandstone bowlders may be seen; now and then an Oriskany bowlder was noted elsewhere on the sheet, but nowhere else were they numerous enough to attract attention. So far as I am aware the nearest outcrop of the Oriskany formation is found in Cayuga valley east of Union Springs. Small bowlders and pebbles of Medina sandstone, while not plentiful, may be found especially in the sections of kames.

Of Local Origin. In a few localities bowlders of local origin are so conspicuous that special reference should be given them. For a few miles north and a mile or so south of Lickville, a region where the drift is thin, the percentage of local material is very large. Bearing in mind that the general movement of the ice here was from the northwest, and noting on the topographic map the rock salients southwest of Moravia, we understand how the

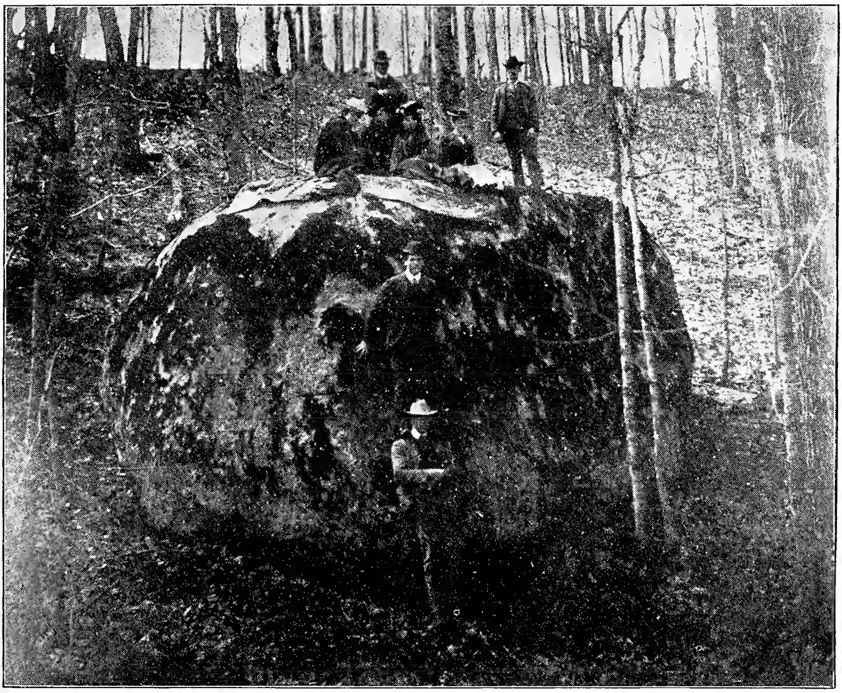


Fig. 20. A bowlder clinging to the steep west wall of Skaneateles Inlet valley.

moving ice took on such a load of local débris. Again, south of Locke, where the altitude reaches 1200 to 1350 feet, the large amount of local material in the drift is evidenced by the stone fences, as well as by the great heaps of stone gathered in tilling the land. Other areas, both of ground moraine bearing a high percentage of local bowlders, and of accumulated drift deposits likewise large in its amount of local sedimentary rocks, were observed on the sheet, but the two localities mentioned are typical.

Crystalline Erratics. A few areas where the foreign element of the drift is large, and the individual bowlders also of unusual dimensions, will be referred to. East of the highway leading northward from Sempronius several very large crystallines may be seen; at the head of the short valley extending westward from Locke, the drift knolls are dotted with erratics; about one mile northeast of Benson Corners, at the general altitude indicated by the 1400-foot contour, the bowlders are numerous and large. Another area of abundant foreigners is the slope of the hill southeast of Como; a Bench Mark of the United States Geological Survey has been fixed in a large bowlder in the field a short distance from the highway which skirts this slope.

A few bowlders conspicuous because of their unusual size were located. Near the first house on the west side of the road north of the Tully limestone ledge, which is crossed by the highway leading northward from Moravia, is a granite bolder showing 10½ feet by 8 feet by 4 feet above the ground. On the farm of S. C. Gooding, about a mile east of Groton, is another very large bowlder. The largest bowlder found in the quadrangle may be seen on the steep western wall of Skaneateles Inlet valley in a wood lot belonging to E. Griffin; its location is a few rods south of the overflow channel (p. 432) which has incised this west wall. The size of the bowlder may be judged from fig. 20.

Ice Dammed Lakes.

Some of the high level lakes of this quadrangle have been studied by Fairchild and by Watson. Their study has been particularly along the line of correlating deltas and locating overflow channels. They mention old deltas at Moravia and in the vicinity of Locke.

Plate XII refers by letters and dotted outlines to the several high-level deltas of the sheet. I will discuss these deltas in the order in which they are designated.

"A." The village of McLean is built mostly on a delta (fig. 21) the altitude of which is about 1120 feet. The southern segment shows the best development, as northward these gravels have suffered much from post-Wisconsin stream work. The lake in which this delta was accumulated evidently was of short duration. It is remembered that southwest of this area, towards Malloryville, the valley is completely blocked with kame moraine;

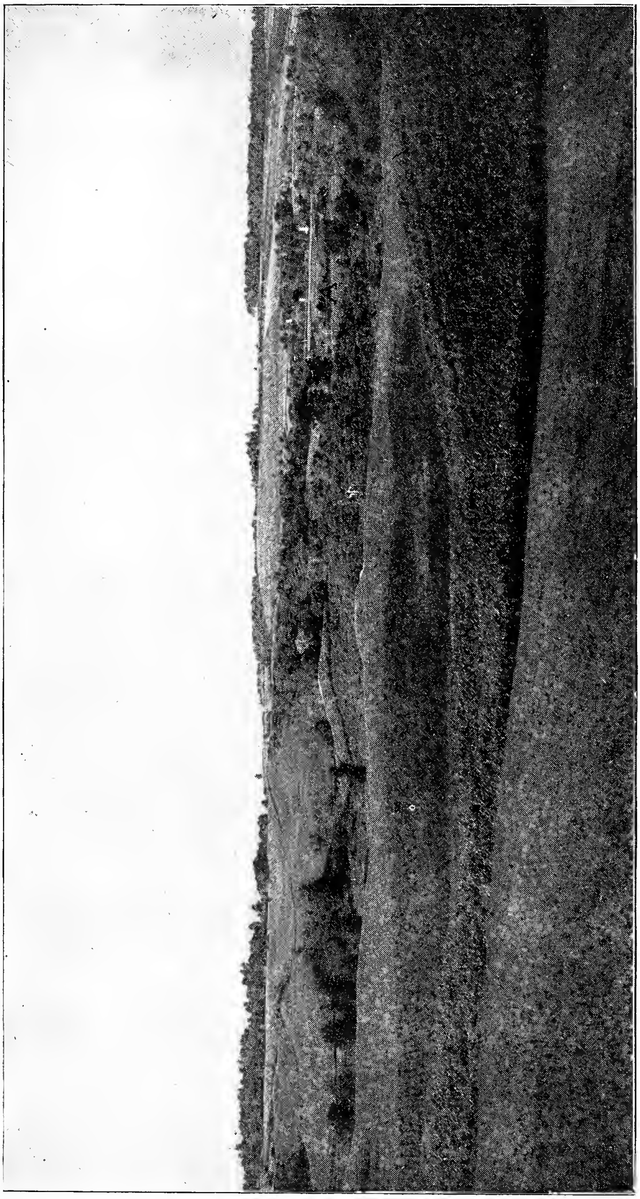


Fig. 21. Kame deposits in vicinity of McLean. Delta "A" shows near right side.

the present course of Fall Creek between these villages is an indication of the irregularly deposited drift that there fills this valley. This lake, if it persisted long enough, must have tended to level off the drift hills approximating its altitude.

"B." This delta is about one mile north of Groton on the east side of the valley. The triangular area marked off by highways lies entirely within the delta. Its slope is gentle, rising from about 1010 feet at the margin to 1035 feet eastward; its area is approximately a square mile. As the lake in which these sediments were laid down gradually lowered, the delta-forming stream from the east evidently hesitated between two courses. Along its eastern margin running southward is the course of a temporary waterway, while the final course taken by the stream from the east has dissected the northern portion of the delta. Thus the body of the delta has remained intact. (Fig. 9).

"C." This delta is adjacent to morainal loop "F" (p. 358); it lies on the same side of the valley, but one and one-half miles north of "B." Its general level is 1120 feet. Along its northwestern side there is an ice-contact slope; here also clay is abundant in the delta plain. In genesis, then, this delta is closely associated with a halt of the valley tongue. Further consideration, however, is given this point in the section where I discuss the static bodies represented by these deltas.

"D." This delta is in the valley bottom about a half-mile southeast of North Lansing; it has but slight development, nevertheless it is typical both in outline and in surface slope, ranging from 980 to 1000 feet. The delta was laid down by a stream flowing from the east. Its serrated front as well as the valley bottom to the west contains a conspicuous quantity of sand.

"E." South of Locke is a delta approximating two square miles in area, and ranging in altitude from 855 to 905 feet. Obviously it represents the work of a stream flowing from the west (fig. 22), and the development evidently attained is not due entirely to stream deposition. A few scattered sections, particularly along the eastern margin of the delta, disclose deposits of till, showing that the load of the stream emptied here into a static body has tended to even up the former irregular morainic topography in this triangular area. In this connection I would mention the fact that practically the whole delta surface is unusually stony, attesting the torrential character of both the major delta-making

Fig. 22. Looking southward through Owasco valley from a point, about 1100-foot contour, on the valley wall west of Locke. Delta "E" occupies the central area of the view; its eastward slope is obvious. The present stream from the west flows at the foot of the slope in the foreground, or along northern edge of the delta.

stream and the many short waterways coursing down the steep slope south of the delta. The surface of the delta likewise shows many distributaries. The permanent post-glacial drainage from the west lies at the foot of the northern wall of the valley, skirting the delta; a slight brook also has sectioned its southern portion.

"F." The local gravel pit at Moravia is in this delta, the surface of which averages 885 feet in altitude. Fig. 23 gives a general view of the crest of this delta. Stream erosion near its north side

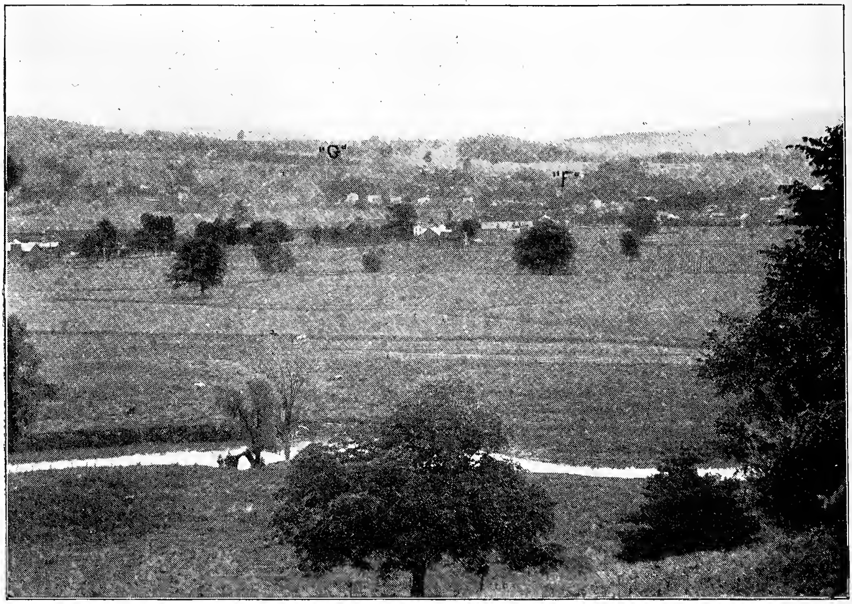


Fig. 23. Deltas "F" and "G" from west slope of valley. Camera stands about 200 feet above floor of valley. Inlet stream shows in foreground.

reveals till deposits beneath the gravel. This same relation of unmodified drift has been disclosed also by the creek flowing westward from Montville. The village cemetery between Moravia and Montville is located on this delta. No development of it was mapped with certainty south of the highway from Moravia to Montville which follows, for the most of the distance, the bed of an inter-, or abandoned post-glacial stream.

"G." This is the largest delta of the sheet; views of it are shown in figs. 23 and 24. In altitude it ranges from 1010 to 1060

Fig. 24. Looking northeastward along a stream terrace in delta "G." This terrace shows on topographic map.

feet, and because of post-glacial erosion, it has been so dissected by a meandering stream and altered by resulting aggradation as to suggest two deltas rather than one. Nevertheless the genesis of these sediments scarcely allows a compound result.

The portion of this delta lying nearer Moravia presents a beautifully serrated front and very typical top. This part has suffered but slightly from post-glacial stream work. The eastern segment, which is just northeast of Montville, presents a very even surface, but a very abnormal front, if one is inclined to consider it a distinct delta. This front, however, is more likely the product of stream erosion. It still bears a suggestion of meander curves and sloping floodplain reaching away from them (fig. 24).

"H." Southeast of Wilson's Corners is a slight but sharply developed delta. In texture its sediments are very fine. Its altitude, 1160 to 1175 feet, indicates a very localized water body, while its slight area suggests a brief period of formation.

"I." Immediately east of Morse Mill is a small but nicely outlined delta ranging from 1880 to 1900 feet in altitude. This delta also shows genetic association with a local body of water.

"J." This sheet includes in the Skaneateles inlet valley a small portion of a delta, the remainder of which is on the Cortland sheet. As this delta is associated with a stream that lies entirely off the Moravia quadrangle, no study was given it.

WATER BODIES WITH WHICH THESE DELTAS ARE ASSOCIATED.

The general history of the ice-front lakes connected with the retreat of the Wisconsin glacier has been worked out with considerable detail in the St. Lawrence basin area. The minor lakes formed in the Finger lake valleys, as soon as the ice had withdrawn northward from the divides at the southern ends, coalesced ultimately into two more extensive levels, one Lake Newberry with its overflow channel at Horseheads, N. Y., into the Susquehanna drainage basin; the other and later, Lake Warren, with an outlet across the "Thumb" of Michigan into Lake Chicago. (1) Lake Newbury, according to the geologists who have given it special attention, represents the coalescence of glacial lake Seneca and high-level water bodies to the east, principally of the Cayuga and Owasco valleys. (2) The expansion of Lake Newberry, as the Ontario lobe withdrew northward, resulted in a

great areal increase and a drop in its water level of 100 or more feet. The ultimate outlet of Lake Warren was via Chicago, with possibly several intermediate levels due to successively lower channels between the Huron and Lake Michigan lobes; the steps in this history have been described by Taylor.[26] It seems apparent, according to Fairchild,[27] that Lake Warren in its later stage may have had also an overflow to the east as the ice withdrew gradually to the axis of the Mohawk lowland area. Glacial lakes Newberry and Warren are therefore associated with the more general expansion of the ice-sheet. The earlier lakes which progressively united to form these great water bodies were associated with minor lobes that reached southward through the axes of the Finger lake valleys. A consideration of the high-level lakes of the Moravia quadrangle starts, then, with the minor bodies of water which skirted the retreating ice-front.

When the Cayuga lobe reached somewhat south of Ithaca, with one dependency extending into the valley of Sixmile creek, and another towards Newfield, a lake stood in front of each of these minor glaciers, one, Lake Brookton, overflowing by way of Willseyville (Fairchild's White Church spillway), the other, West Danby lake, via Spencer Summit. With the withdrawal of the ice from "South Hill," the salient just south of Ithaca, these two bodies of water coalesced, forming glacial Lake Ithaca, which overflowed by way of White Church. Lake Ithaca endured till the ice had retreated, revealing an altitude lower than that of the White Church spillway; this occurred at Ovid. Lake Ithaca then flowed into glacial Lake Watkins, which escaped southward over a spillway at Horseheads.[28]

The statement has already been reiterated that the region east of Cayuga valley was controlled by the lobe of ice that persisted in this valley long after areas on the same parallels eastward were ice-free. This condition maintained in the Moravia quadrangle a general northeast-southwest position of the ice-front. The study of moraine belts led to this deduction; an interpretation of the high-level deltas further fortifies the conclusion.

[26] *Bull. Geol. Soc. Am.*, vol. viii (1896), pp. 48–53.

[27] *New York State Museum*, Bulletin 106 (1907), pp. 43–44.

[28] The résumé contained in this paragraph is based on the publications of Fairchild. The writer, however, has made a field study of all the localities mentioned.

While it is probably impossible to be certain about the chronology of these deltas, nevertheless in discussing their genetic relations an attempt is made to arrange the associated water bodies in their chronological sequence. In this study only one type of observation has been made in addition to verifying the earlier work of Fairchild and of Watson on the high-level lakes of the region. The overflow channels with which these men have correlated the deltas studied are all located along general drainage lines to the south and west of the water bodies under discussion. After having mapped the bands of thickened drift, one notes that the eastern margin of the Cayuga lobe so abutted the rock salients as to form intermediate overflow levels between the spillways that have already been located. In accordance with these observations the several deltas will now be considered in the order in which it is thought they were developed.

"A." The position of the ice as denoted by the morainic loop southward from Freeville held up in front of it a slight body of water which overflowed through the Dryden valley with a spillway approximately 1207 feet in altitude. This is the first static body of water formed on the quadrangle as the ice retreated. No typically developed delta was observed correlating with it. In the wide valley, however, immediately north of Dryden village may be seen on the eastern wall a well formed alluvial cone which presumably correlates with this level.

But the delta 'A" at McLean, having a general altitude of 1140 feet, obviously represents an overflow channel, one wall of which was the ice itself, the other the northwestward slope of Turkey Hill, located on the Dryden sheet. The water thus had its ultimate outlet through Cascadilla valley by way of Ellis, and thence into the glacial lake that occupied Sixmile creek.

"C." As already stated, this delta is associated with a morainic loop of which it almost forms a part. Its level coincides closely with that of "A," but it is not of contemporaneous development; while these two deltas correspond in altitude, "C" is of much later origin; its position is such that a marked accumulation of aggraded material developed in a fairly short time. The loop of drift reaching across the valley at this point attests a stationary position of the ice for some period during which there poured along the eastern side of this ice-tongue a vigorous stream whose gradient suddenly changed, as may be observed on consulting

the topographic sheet. It is entirely possible that this delta started as an alluvial cone, growing rapidly, and that in the shifting of the ice, a slack or even static condition of drainage developed in the rear of the cone; consequently the final deposition of streamload produced the delta effect.

"B." The well developed delta north of Groton appears to be associated in its earlier stages with a partial withdrawal of the ice from the west slope of Turkey Hill, thus lowering the outlet while still keeping a static body of water, a score or more feet in depth, over the normal divide of Fall Creek valley in the region of Freeville. But after the ice had retreated sufficiently from Turkey Hill to drain Fall Creek valley southwest of Freeville, then this latter divide became the overflow channel of the water standing in front of the ice in the Groton valley. This spillway is given as 1040 feet in altitude.

"H." With the thinning of the general ice-sheet over the Moravia quadrangle the Owasco lobe alone remained, but preceding the stage when the area of this sheet bore only remaining portions of the Owasco lobe there appears to have intervened a period when the eastern flanks of the Cayuga lobe still spread over a part of the western area of the sheet. Delta "H" represents the withdrawal of the ice from the high area east of Wilson's Corners sufficient to allow drainage from the north an outlet between the ice and this slope into the small body of water held up in the Morse Mill valley; this delta has a slight areal extent, but is typical in the usual delta features. It apparently does not represent a long time interval. Its position and development are both in accord with the ice-walled channel outlet described southeast of Moravia (p. 435).

"I." This delta at Morse Mill represents a lower level of the same slight body of water. Its spillway also was formed by the ice and the westward slope of the salient southwest of Moravia.

"G." The portion of delta "G" here referred to lies northeast of Montville and has a general altitude of 1060 feet. In accordance with the distinction made by Fairchild[29] this delta represents glacial Lake Groton which overflowed through Fall Creek with a spillway at Freeville. The great mass of material in this delta bespeaks the vigorous drainage of ice-front streams

[29] *Bull. Geol. Soc. Am.*, vol. 10 (1899), p. 50.

coming from the north. During the formation of this part at least of delta "G," the ice of the Cayuga lobe obviously reached eastward from Ludlowville covering a later overflow channel at North Lansing, covering also the Moravia sheet northward, and connected apparently with the morainic belt east of Asbury. With this tendency of the ice, it is probable that the duration of the Freeville overflow channel was contingent upon the position which the eastern margin of this Cayuga lobe maintained in reference to the high area south of Asbury, that is, the rock hill in the southwest corner of the Moravia quadrangle. When the ice crept down this western slope, disclosing a contour lower than 1040 feet, it is evident that the waters of the glacial Lake Groton worked along the edge of the Cayuga lobe and flowed into glacial Lake Brookton. The western slope of this hill shows the effect of such a spillway.

As just indicated the water level connected with delta "G" gradually dropped to an overflow of about 1020 feet, which we will call the Asbury spillway. In consequence, this delta has a lower stage during which it developed westward from the part above described; the feeding stream, when the lake-level fell, took a course near the western part of the old delta. The difference in level between these two parts of this delta is shown in figure 24. The highway leading south from Asbury for some distance passes over a rock surface from which the normal veneer of drift has been largely removed by the outflowing waters of this lower stage. It is evident that this relation of ice and topography south of Asbury was maintained for considerable time, a position of the ice probably marked by drift loops in Fall creek valley on the Dryden sheet.

"D." This delta, meagre in development, apparently also represents an overflow by way of Asbury; its altitude is about 940 feet. Furthermore, it seems to mark the critical stage in the history of glacial Lake Ithaca, a stage that immediately preceded the formation of Lake Newberry. This delta is a short distance west of the Lansing overflow channel, and was developed during and shortly after the time when static water stood over the channel. Its height and areal extent both indicate a brief duration of the water body which it is associated with.

"E." The Locke delta, as already pointed out by Fairchild[30]

[30] *Loc. cit.*, p. 50.

and by Watson,[31] represents the level of Lake Warren. Its general altitude is 865 feet, but it blends westward into slopes, alluvial cone or delta in origin, that suggest a gradual lowering of the waters from the Lansing overflow channel. The sharper development of the delta, however, is associated with the lower level.

"F." Delta "F" correlates with "E" at Locke. More recent erosion has removed much of this gravel from one-half of the valley as far upstream as Montville. Post-glacial stream-work also has creased the northern slopes of the delta, revealing buried drift which often is very bowldry. The top of delta "F" has a gentle southward gradient. Both this fact and its frontal outline indicate a rather speedy decline in the level of the Lake Warren waters. Figure 23 gives an idea of the general outline of the delta viewed from the west wall of the valley.

Smaller Deltas. The above list includes the more conspicuous areas of delta gravels. Each level thus indicated marks also the altitude of many minor accumulations of gravel at the mouths of secondary streams. These smaller deltas are particularly common along the Freeville-Moravia valley. A delta fan of considerable size shows at Peruville, and apparently correlates with the lake level indicated by deltas "A" and "B", overflowing by way of Turkey Hill. South of Locke, on the eastern side of the valley, several of these minor deltas show. Another marks the outlet of Dry Run, south of Moravia.

Other Lake Phenomena. The dimensions of some of these deltas, particularly "G" and "E," suggest a static body that endured for some time. When, however, we consider the torrential condition of drainage incident to the retreating ice-sheet, and the fact that load was easily acquired by all streams, there being little vegetation to retard degradational agencies we realize that in a relatively short time a great quantity of gravel accumulated at the mouths of these streams. Consequently the other shore phenomena which we are accustomed to connect with water bodies did not attain much development in this quadrangle; some of the lakes had a brief existence; some were so slight in area that very little wave work was accomplished.

In the valley south of Moravia, also in the neighborhood of Lake Como (fig. 15), and again southwest of McLean was noted the

[31] *Loc. cit.*, p. 193.

general flat-topped appearance of many drift knolls. These flat tops correlate with water levels; originally they projected somewhat higher, but probably never very far above the range of wave work, and therefore were leveled off.

Along the Freeville-Moravia valley I observed on drift slopes some benches that apparently correlate among themselves, forming different levels, suggestive also of wave and current work. These benches show to best advantage in the spring of the year when snow persists longer in the angle between the cliff and terrace.

Just south of the mouth of Dry Run are two terraces cut in the rock. These are the only instances of terraces in rock, possibly produced by waves, which I noted in the quadrangle. One of them corresponds to a lake level. In the absence of other such terraces, I would not interpret these as due to wave work.

No bars, spits, or other phases of shore gravels, were noted. The period during which these lakes stood at any given level hardly sufficed for phenomena of this type.

Post Glacial Tilting. Up to this point no reference has been made to the changed altitudes given these deltas by tilting subsequent to their formation. The value of this factor for any particular gravel terrace varies directly with its distance north of the spillway used by the static body in which the terrace was constructed. The first data referring even indirectly to this deformation have been supplied by Dr. G. K. Gilbert who estimates that the postglacial tilting of the Iroquois shore line, in this part of the state, is 2.7 feet per mile.[32] Only on the assumption that no land warping took place in this area during the time that intervened between the formation of the deltas we are discussing and the development of the Iroquois shore line does this factor apply. On this assumption, then, it follows that the highest delta at Moravia, constructed in a water body which overflowed by way of Turkey Hill, is now approximately 42.9 feet higher than when it was formed. The assumption of stability of the land surface during the interval between the Turkey Hill overflow level and the level of glacial Lake Iroquois is too remote to give these figures much value. It is reasonable to assume that the levels existing while these higher deltas were being constructed, because of sub-

[32] Quoted by Tarr: *Jour. of Geol.*, vol. xii (1904), pp. 79–80.

sequent pre-Iroquois land warping, intersected the water-level which developed the Iroquois shore line. This suggestion would merely call attention to the futility of applying the measure of land tilting established through a study of the Iroquois shore line to the water levels of antecedent lakes.

Alluvial Fans. Some alluvial fans connected with higher water-levels have been noted. One, particularly well-developed, exists at the mouth of the valley into which esker No. 3 leads (p. 395). Another is connected with Hollow Brook, southwest of Locke. The over-deepening of the Owasco valley by glacial erosion has favored the construction of alluvial fans now noted near the flood plain; north of Moravia, on the west side of this segment of the valley each house, along the valley road, stands on such a fan; some of these are conelike in steepness. A few fans are found also on the east side of the valley.

Glacial Erosion.

As in all glaciated areas, the round-topped hills (fig. 18) of the higher altitudes in the Moravia quadrangle suggest the erosive work of an over-riding ice sheet. The details of this process imply both abrasion and plucking as the ice closing about the elevations first modified them through freezing to and transporting the blocks already loosened by weathering processes. It is probable, however, that the tendency of over-riding ice to modify the higher points into rounded domes cannot work itself out typically save in areas of crystalline or other rocks of homogenous structure. Regions of sedimentary rocks, particularly where the beds are thin and somewhat irregular in structure, do not have the nicely rounded domes that elsewhere indicate ice-carving.

Looking southward from a position well-up the valley wall near the foot of Owasco lake one sees most convincing evidence of the power of ice as an agent in altering valleys. While the valley seems wide, and the upper part of its walls have a slope corresponding to the age indicated by this width, yet the depth of the valley is all out of harmony with these characteristics. The gentle slope of this upper part of the walls changes suddenly to a declivity, continuing steep down to the flood-plain. At, and north of, Moravia on both sides of the valley the highways ascend these slopes only by laboriously swinging far to the right and left while

making relatively a slight ascent. And for several miles at a stretch no roadway-construction has been attempted. The vertical measure of the steep part of the side walls is 300–500 feet, but we have no proof of the amount of glacial over-deepening in this valley; the deepest well, 200 feet, is near the east wall of the valley at Moravia and did not reach rock; a conservative estimate of the measure of glacial erosion here would be 1000 feet.

These steep walls are remarkable, but their continuity, giving the valley a canal-like effect, an artificial appearance, is more remarkable. Rivers widen their valleys by cutting alternately against the two walls; thus we generally find a steep slope directly across the valley from a gentle slope; a long-range view through such a valley is broken by spurs each hiding the end of the next one beyond but belonging to the opposite valley-wall. Glacier ice is the only agency known to smooth and straighten the sides of a valley.

When glacial erosion thus alters a valley, deepening it and cutting back the lower parts of its walls, an abnormal relationship is established between the major and tributary streams; the latter, instead of flowing into the former at an even grade, drop over falls or tumble down cascades in many instances several hundred feet. The immediate base-level of a branch stream is the main stream, and save in very exceptional cases the branch lowers its bed in unison with the major. But after a valley has been glacially over-deepened the tributary streams commence to adjust themselves to the new base-level, and in consequence have cut rapids and gorges; these tributaries then ocupy "hanging valleys.' Fall Creek valley in the vicinity of Dresserville, and Skaneateles Inlet valley also show the result of vigorous glacial erosion.

Similar evidences of the work of glaciers have been observed in many parts of the world. That ice has done work of such magnitude, there is almost unanimous agreement among scholars. Of necessity, it is impossible to study the actual process of glaciers eroding valleys. In some mountainous regions at the present time glaciers of the alpine type are at work; the portions of the valley from which such ice has recently withdrawn show plainly what has been done: a U-profile has been developed, making the valley deeper and its bottom broader; the sides and bottom, where bare, show scouring, polishing, and scratching, the work of stones of all sizes held in the basal and lateral parts of the valley glacier.

Hence it is concluded that the over-deepening of valleys is accomplished slowly by the stone tools plowing and rasping the solid rock; the nature of the surface being eroded, the quantity of the tools, the pressure of the ice, and the time through which these continue to act are factors in the process.

The conditions that govern the erosive work of an alpine glacier are probably very much the same in nature as operated in a continental glacier, but the pressure of the ice in the two cases is quantitatively different. The degrading tools are held to their work of erosion by the weight of the ice mass above; for this reason, the longitudinal valleys of central New York were altered by the ice cap. Rock in valleys always sustained a greater pressure than rock of the upland; hence the valleys suffered more erosion, thus supplying the tools for sustained erosive-work. Furthermore the shoe of ice filling the valleys bore down heaviest on the valley-bottom, the pressure decreasing up the side walls as the thickness of the ice also decreased, but not proportionally with the ascent for the reason that the ice-shoe tends to spread laterally under weight. This lateral pressure combined with the vertical pressure produces the U-profile, an erosion-product never arising from the work of water.

Any discussion of conditions that obtained during Pleistocene times must be partly theoretical. In quantity of ice, Greenland affords the nearest approach to a continental glacier; in the interpretation of the features that probably characterized the margin of the Pleistocene ice-sheet, Alaskan studies have been most helpful.[33] The alpine glaciers are strictly analagous to the valley dependencies of the great ice-sheet only when it fronted in mountainous topography. The gradient of the valleys of central New York was generally towards the ice, hence the conditions were quite different from what is seen today in the Alps. It is largely by inference based on such facts as observers have recorded in the above regions, and on the distribution and nature of the drift sheet itself, that we interpret the varying mode of its origin, and reconstruct the shifting outline of the ice-front.

The most conspicuous feature of glacial work is the stupendous erosion seen in some valleys. In other valleys deposition took

[33] Tarr: *Zeitschrift für Gletcherkunde*, band iii (1908), "Some Phenomena of the Glacier Margins in the Yakutat Bay Region, Alaska," pp. 81–110.

place. The variation of valleys from transverse or from longitudinal positions is attended by a corresponding variation in erosion. The Moravia quadrangle has several valleys maintaining various attitudes between the transverse and longitudinal positions. Remembering that the ice in this area did not have a meridional motion, we understand the unequal erosive effects in these valleys. For example, a valley extending southeastward from Freeville bears quite a transverse relationship to ice-motion, whereas certain segments of the more longitudinal valleys (fig. 4) are quite in line with the deployment of the moving ice. The valleys that approach a transverse position suffer modification largely through partial burial. This is particularly the case when they happen to coincide with ice halts.

The development of extended and fairly steep valley walls is not normal to regions having slight vertical variation in stratigraphy. The development of drainage lines, and the resulting disintegration of terranes, produce side walls more or less irregular in reference to the axis of the valley. In a longitudinal view this condition gives the effect of over-lapping spurs.

From Locke northward the Owasco inlet, as already stated, especially on its western side has an oversteepened valley slope such as would not normally be developed in the stratigraphy. On the eastern side from Moravia northward the same condition exists; the exact nature of the valley wall on this side, southward from Moravia, is partially masked by drift accumulations. But this segment of the Freeville-Moravia valley does not have overlapping spurs, a consequence of the active ice-erosion in this longitudinal valley. There is conclusive evidence that the northern half of the Freeville-Moravia valley is genetically due to the same direction of stream flow that the valley now has. This being the case the rock floor had a general northward gradient, and accordingly offered the moving ice the condition of obstruction conducive to a great amount of erosion.

The same principles of ice-erosion in longitudinal valleys is illustrated by the steep rock slope extending from Morse Mill southeastward to the vicinity of Lake Como. Again, in the valley of Skaneateles inlet we have these oversteepened slopes on both sides, so far as this sheet is concerned (fig. 5), due to ice erosion.

When glacial-deposition does not later take place in localities of active glacial-denudation we find barren farms as on the steep

slopes lying between West Groton and Locke; likewise on the two salients southeast of Moravia, as well as several northward sloping areas found on the eastern side of Fall Creek valley northward from McLean. Of a similar genesis too are some scattered areas in the southwestern part of the quadrangle. This condition in the uplands has been discussed as illustrating areas where the till is thin (p. 381). The slopes alluded to afforded the ice the proper obstruction attitude for very effective erosion.

In general, however, the subject of ice-erosion is thought of as applying more particularly to longitudinal valleys. Is the entire transverse profile of a valley altered by ice, or is the erosion confined largely to the lower parts? The observations bearing on this point, made in the Moravia quadrangle, are best illustrated in the Freeville-Moravia valley northward from Locke. As mentioned above, this segment of the valley offered the most favorable conditions for ice erosion. A generalized statement of the conclusion from the data observed is: In this longitudinal valley the most vigorous erosion was operative along the contours below 900 feet. Above this plane is a zone of less active erosion, while still farther up the ice did considerable abrasive work. In the lower contours of the valley, however, the power of an ice sheet to deepen longitudinal dissection lines is very impressive.

The above generalization is based on a detailed study of the slopes, and upland above the 900-foot contour; what the ice did below this general altitude of 900 feet is perfectly clear. Folded beds, rather completely disintegrated, shown in figure 25, may be seen in a quarry a short distance northeast of Locke. The fold as exposed in this cross-section, which is oriented S. 30° east, has a tilt of approximately 51°. The disturbed zone is but a little over one foot in thickness and is made up of thin sandy shale layers beneath which is a sandstone bed about six inches in thickness. The quarry has been opened for removing the heavier beds which are subjacent to this six inch layer of sandstone. Overlying the distorted beds are about two feet of drift and quarry rubbish, the till part of which in all probability is not in place.

Figure 26 shows another folded horizon a mile and one-half north of Moravia. This fold inclines about 36°, and the exposure is in an east-west line. The folded area is on the eastern slope of the valley, and the fold itself is turned against gravity. Here too the disturbed beds, about eighteen inches in thickness, con-

sist of shale and sandy layers. Overlying the disturbed zone is very compact ground moraine from three to four feet thick. It should be stated further that the disturbed beds are underlain by a hard sandstone layer over which the stream is now flowing.

A similar disturbance was seen in a recent stream cut about a quarter of a mile northeast of the folds just described. Here too it should be noted that the fold is turned against the slope.

Fig. 25. View in a quarry east of Locke; shows weathered thin bedded strata folded by glacial ice. The exposed plane is approximately parallel to the last movement of ice.

Origin of These Folds. In other localities it has been noted that freezing and thawing is competent to produce anticlinal disturbances in sedimentary beds. Under normal conditions folds thus produced should be symmetrical and the disturbed beds should blend vertical y into more and more residual soil; a gradual transition likewise should be noted in the opposite direction;

where beds are so deeply buried this explanation is not applicable. The area shown in fig. 26 is below the normal frost line for this climate. Fig. 25 gives a section the upper part of which is subject to frost; there is evidence here of frost alteration in the apex of the fold, but this fold is so unsymmetrical that the frost theory cannot apply.

Folds due to creeping are not uncommon especially in the horizons of thin beds. The factor which induces the disturbance

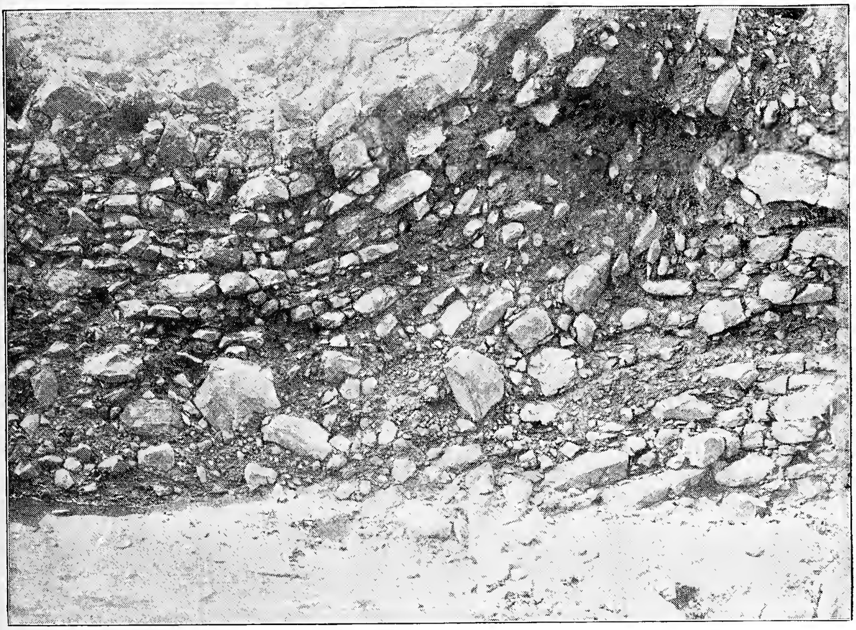


Fig. 26. This view shows subjacent strata disturbed by the outward or lateral motion of an ice-lobe.

is gravity. A fold then which is turned in a direction contrary to the supposed force of gravity cannot be thus explained.

In glaciated countries it is very probable that the superficial rock horizons when removed by glacial erosion and other methods of ice disintegration no longer subject the underlying strata to the normal burden of their weight, and in response to this removed pressure these underlying horizons doubtless buckle, producing a fold. Such folds, however, should always be symmetrical or at

least approximately so, and should likewise show the effects of rather speedy giving away to certain stresses. This type of fold probably is represented in the Moravia quadrangle, one example at least having been noted. But the folds in question cannot be explained as due to buckling.

Campbell[34] has described folds which result from normal weathering of superficial formations. The weathering being localized along joints, there results, particularly when these joints are numerous, a very appreciable lateral extension which at some point in the horizon overcomes the normal pressure and produces a fold. Both the mode of production and the type of fold produced, which in all cases illustrated are symmetrical, preclude this explanation for the folds in question.

The only remaining explanation seems to be that of over-riding ice. We have little data of exact observation detailing the method of ice-erosion. When the country being transgressed bears a mantle of residual soil, this is removed before the less weathered horizons become subject to ice abrasion. Considering the great weight of over-riding ice, we apprehend that friction between its base and the underlying surfaces accounts for the removal of great areas of partially weathered rock. The distorted horizons above figured seem in harmony with such a method of removal. This being the case, then, these folded horizons indicate a zone where ice-erosion has been less efficient.

Fig. 25 shows that the direction of ice-motion was more nearly north-south. Fig. 26, in which the fold is turned eastward, implies a flow of ice in that direction. The former locality, is quite in line with the direction of ice-motion for this region. The latter locality suggests rather a movement of the declining Owasco lobe, when on the eastern side it fed outward from the main axis of the valley. This outward movement of the ice in valley lobes has long been known. These figures therefore illustrate both linear and lateral motions of the Moravia lobe.

The areas shown have been selected from several photographs; some of them, however, represent less distortion.

As already suggested, theoretical considerations point to greater activity of ice as an eroding agent in the lower contours of these longitudinal valleys. On the west side of the valley south of

[34] M. R. Campbell: *Jour. of Geol.*, vol. xiv (1906), pp. 226–32.

Moravia, at an altitude of about 820 feet, a polished and striated surface attests the vigor of the ice action; that plucking was a part of the process of disintegration is evidenced by the several stages of rounded edges, farther down the slope, developed after the removal of rock along bedding planes. The basal load was sufficient for most active planing or abrasive work. On the same side of the valley but northward, similar striated and polished surfaces have been noted. Also on the opposite valley wall, the vigor of the ice is indicated by the well rounded and polished ledges. Southward from Locke, however, evidence of this nature is wanting. In general it may be said that evidence of the most active ice-erosion is not found over 150 feet above the present flood plain.

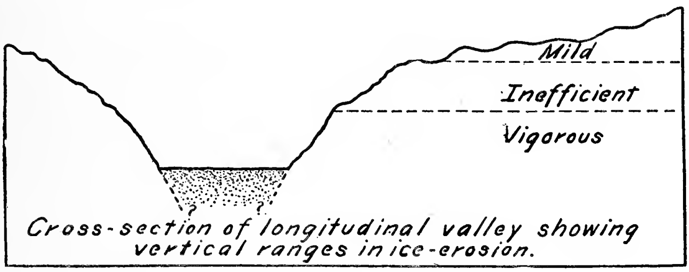


Fig. 27. A generalized representation of glacial erosion in a longitudinal valley. The observations on which this deduction rests were made about the Owasco valley from Locke northward.

The resultant, then, of ice-erosion is to deepen longitudinal valleys, producing oversteepened walls, the horizon of accentuated erosion commencing in the Moravia valley somewhat below the 900-foot contour. Consequently, in cross-section, valleys that preglacially had a sharp V-outline, are given more of a U-shape outline, while mature valleys are made composite by having a U-outline cut approximately along their normal axes.

Fig. 27 attempts to generalize the results of ice-erosion which, in accordance with the above discussion, may be given three ranges showing variation in effectiveness. First, in the highest altitudes, a range of mild erosion; second, next below, a range of inefficient erosion; and third, toward the valley axis, a range of vigorous erosion.

Whether this enormous over-deepening of certain valleys was accomplished by the ice-sheet while the margin was far south,

or by the fringing tongues or dependencies that fed out into the valleys as the ice-sheet advanced and again as it retreated, and whether more erosion was done by the Wisconsin ice than by an earlier invasion, are pertinent questions. Observations made in the Ticino valley of Italy,[35] and in other valleys through which glaciers have fed from mountainous regions, indicate that valley glaciers performed much erosion; but in these valleys the ice moved downhill, whereas in central New York the valleys sloped the other way. Furthermore in New York there is evidence of erosion, as in the Laborador pond valley of the Tully quadrangle, producing a "through" valley where apparently two streams formerly headed against each other. It does not seem to be clearly demonstrated that over-deepening and "through" valleys are the products solely of valley glaciers. Again, if the erosion of the Owasco valley was accomplished by dependencies of the retreating Wisconsin ice we should find drift-loops in the parts of the valley not now drowned by the lake, and in the lake part lateral moraines correlating with loops; on the Moravia sheet I did not find loops near enough to the over-deepened part of the valley to indicate that the erosion was due to tongues of ice appended to the retreating Wisconsin sheet. If an earlier invasion did not extend farther south than the general location of Chamberlin's "Moraine of the Finger Lake Region,"[36] we can conceive how the alteration of these valleys may have been accomplished by glaciers somewhat of the alpine type, belonging to a pre-Wisconsin ice-sheet.

Striae.

The thin drift in many portions of the uplands, and the altitude of the axes of rock salients have made obvious the direction of ice-motion over several parts of the Moravia quadrangle. While many scores of readings were taken in the particular areas, the average of these in most cases has been used in Plate XII which locates the most pronounced striated surfaces.

The glacial scratches we now read represent in the majority of

[35] W. M. Davis: *Appalachia*, vol. ix (1900), "Glacial Erosion in the valley of the Ticino," pp. 136–56.

[36] U. S. Geol. Surv., *Third Annual Report* (1883), pp. 353–60.

cases, the direction of motion of the retreating ice-body; and, as had already been discussed, the local topography is a deciding factor in the direction of these latest movements. Therefore, it is an open question whether the glacial scratches in the vicinity of valleys, after all, give much information as to the movement of the general ice sheet. The discordance in the appended table of striæ between the lower and the higher ranges of altitude show the influence of topography.

It is apparent that the general movement of the ice in the Moravia quadrangle was from the northwest, such is the indication of striæ on higher altitudes. This prevailing direction of ice-motion does not necessarily imply that the general ice-sheet thus moved. As explained on earlier pages, the controlling lobe of this vicinity occupied the Cayuga valley which lies to the west. The lines of ice-movement, as has been established in several distant parts of the country, is always outward from the axis of such a lobe. If then the Cayuga valley lobe controlled the last movement of ice in the Moravia quadrangle there is accordance between the hypothesis and the direction of striæ.

In the whole area of this sheet but one locality was found indicating a direction of ice-movement from any other quadrant. Near the eastern margin of the sheet, a mile or so northeast of Rogers Corners, a dimly striated surface exists on the very top of a hill which the topographic map makes 1720 feet above sea level. These scratches are mere brushings, and the first time I noted them they were not read, feeling that they represented some accidental alignment of plough or road scraper markings. Later in this season, however, the same faint markings were again observed, and read. The next summer this area was visited, and the evidence of dim striations was read on still a different side of the highway. The average direction of these several readings is S. 45° W. The faintness of the brushings, and the weathered surfaces carrying them, both indicate greater age than do the striæ elsewhere on the sheet. The topography eastward suggests that this area may have been finally controlled by ice which moved towards the southwest, just as the ice of a lobe farther west has affected other parts of the sheet by the striæ trending to the southeast. On the basis then of control of ice-motion by the drainage lines eastward, we may account for these discordant striæ; and on the supposition that they present the work of the oncoming

Wisconsin ice-sheet we may understand their weathered and indefinite condition.

Few of the striated areas present much variety in direction. In only a couple of cases is there sufficient discordance to suppose that the scratches are not contemporaneous in origin. Southeast of Moravia between the 1400-foot and 1500-foot contours there appear to be two sets of striæ, one of which averages S. 72° E., and the other S. 41° E. On the rim of the Montville valley, where it drops into the Moravia valley, we also find discordant striæ, one set of which has the direction S. 51° E., and the other S. 26° E.; the first mentioned set evidently represents the more general movement of the over-riding ice, while the second is plainly the result of local topography.

About a mile southeast of Sempronius in a saddle between two prominent rock hills we find conclusive evidence of a minor tongue which fed across and through this sag. The vigorously striated surface here gives an average reading of S. 76° E., while the valley to the west obviously directed the ice in a general southeastern motion. A similar instance is also noted southeast of Nubia where the striæ average S. 73° E.

One mile west of Locke is an area which apparently gives us the motion of the general ice mass. The average course of the striæ here is S. 44° E. If these striæ were connected with the out-moving-ice from the Moravia lobe their normal direction would be a similar deflection to the west. There is no evidence at all showing that the Owasco valley ever induced a lobation of the ice-front sufficiently strong to offset the controlling influence of the Cayuga lobe.

Grouping the direction of striæ according to ranges in altitude it is seen that those found below the 1100-foot contour average S. 39.2° E.; those between 1100 and 1400 average S. 52.6° E.; between 1400 and 1700 the average direction is S. 69.3° E.; while the only striated surface above 1700 is the indefinite one already alluded to where the direction is S. 45° W.

The following table gives a condensed résumé of the principal striated areas arranged according to altitude; each direction represents the average of a great many individual readings:

800–1100	11–1200	12–1300	13–1500	15–1700	17–1800
S. 14° E.	S. 75° E.	S. 44° E.	S. 46° E.	S. 61° E.	S. 45° W
S. 26° E.	S. 57° E.	S. 50° E.	S. 48° E.	S. 71° E.	
S. 51° E.	S. 37° E.	S. 56° E.	S. 31° E.	S. 76° E.	
S. 66° E.		S. 51° E.	S. 49° E.		
		S. 45° E.	S. 55° E.		
			S. 72° E.		
			S. 73° E.		

Ice-Front Channels.

The several halts of a retreating ice-sheet naturally develop waterways not normal to ordinary conditions of rainfall. Often these waterways are narrow, occupying a slight depression sometimes incised in rock; more often, however, they are not cut entirely through the previously deposited drift. Again, they are broad channels indicating a wide shallow stream bearing drainage away from the melting ice; in this case an unusual quantity of bowlders, large and small, generally characterize the former water course. These bowlders may represent the unremoved heavier portions of the former drift deposits, as well as the débris melted from stranded ice-blocks being floated off by the waters flowing from the front of the glacier.

The two types of ice-front channels may be discriminated: (1) *Topographic*, or drainage ways usually following the sags between or leading into the valleys of the locality; (2) *Torrential*, or channels cut generally in previously deposited drift, and having locations possible only when an abnormal quantity of water is turned loose through an area that in post-glacial times has never carried any considerable drainage. The former type one might locate with some degree of accuracy on a topographic map, knowing only the general positions of bands of thickened drift. The torrential type, however, can scarcely be hypothecated on any normal premises. Ice-front channels of this type are found often in unexpected places, particularly where the ice has melted slowly and the drift in consequence has become very thick.

Topographic Type. (1) About a mile southwest of West Dryden is an area now covered by extensive swamps. This flat region leads away from northwestward falling contours to contours descend-

ing in the opposite direction on the Dryden sheet. The plentiful bowlders, as well as the suggestion of a channel toward the northern margin of the flat area, both indicate ice-front drainage. In some places it is evident that the drift has been quite completely swept away; this is particularly true in the crease which is indicative of a channel, cut by the narrower, more permanent form of the overflow stream.

(2) West Groton is situated on the northwest corner of a quadrangle formed by highways. Just south of the diagonally opposite corner from West Groton is a channel which lies slightly north of the axis of the valley leading southeastward to the village of Pleasant Valley. This channel dissects a loop of drift already described. It is a well marked crease, though it does not disclose the underlying rock.

(3) Beaver Brook, a tributary of Fall Creek, heads in a channel southeast of Lafayette. The channel here indicates a long period of overflowing glacial waters. The lateral tongue of ice from the lobe that persisted in Fall Creek valley stood for a considerable period in this valley, the drainage from which incised the overflow channel referred to.

(4) Another tributary valley of Fall Creek valley, leading southeast from the parallel of Rogers Corners, also was similarly occupied by a lateral tongue of ice, the drainage from which developed a channel leading into Dry Creek of the Cortland quadrangle. Fig. 12 gives an idea of the morainic accumulations built up during this halt of the ice.

(5) Again the tributary valley east of Como caused an analogous arrangement of drift and overflow channel. This channel likewise carried waters into a valley of the Cortland quadrangle.

(6) Leading eastward from the plexus of drift in which Fall Creek rises is a channel of glacial overflow incised in the rock, and leading into Skaneateles Inlet valley. This channel has already been alluded to under the discussion of drainage (p. 343). To some extent its development may be of post-glacial origin. The manner in which the drift north and west from the western terminus of the rock gorge portion of this channel has been eroded indicates that the post-glacial factor in its degradation is very unimportant.

(7) In connection with the formation of the drift loop just east of North Summer Hill the ice-front waters developed a channel

that has swept off much of the ground moraine leaving the surface of the country rock quite exposed. Reference was likewise made under the general consideration of drainage (p. 343) to this ice-front stream which gave the gorge to the southeast its present development. Here, too, the later post-glacial erosion has been slight.

(8) About one and a half miles due northwest of Summer Hill a typical ice-front channel now marks the divide area between Dry Run and the Summer Hill tributary of Fall Creek. This channel is practically of immediate ice-front drainage development. For a time, however, probably rather brief, the channel was the overflow of a slight lake held in the upper portion of Dry Run valley.

(9) Hollow Brook, west of Locke, occupies now for a short distance, near the boundary of Genoa and Venice townships, the course of an ice-front channel, which is crossed by the east-west highway at the point where the present stream occupies the former waterway. The genesis of this overflow channel is connected with topographic relationships found on the Genoa sheet.

Torrential Type. As stated above, this type of channel is confined to areas of thickened drift, that is, areas where the ice-front retreated very gradually. While no pretense is made at mapping all channels of this type, it has been thought well nevertheless to make specific reference to a few of the better developed illustrations, or to vicinities where the type abounds.

(1) On the eastern wall of the Freeville-Moravia valley, it has already been noted that the drift assumes a very morainic aspect. The torrential overflow channel is here common, and is easily differentiated from post-glacial erosion lines. The drainage established since the complete retreat of the ice has suffered but slight changes. Consequently, the deserted channels, since it is evident that they bear no relationship to post-glacial waterways, are plainly of the ice-front type.

(2) In the kame moraine areas from Freeville to McLean and northward one notes illustrations of the torrential type of ice-front channels. This would be expected, for here the massive accumulations of drift, prevailingly washed in character, bespeak an unusual quantity of ice-front drainage. Some of these channels indicate a sub-glacial origin, as it is impossible to associate them with the normal development of channels cut by water flow along

the lines induced by gravity. While only one esker (fig. 18) has been mapped in this region, it is nevertheless possible that some of the short and isolated ridges of washed drift do represent segments of subglacially aggraded drainage lines. It is this association that prompts the above suggestion concerning the genesis of some of the erosion channels noted in the area.

(3) Just a few rods east of the third road to the left going south from Como is a deserted water course which has no connection with recent drainage; its proportions are entirely out of harmony with the work that might be done by the waters assembling from the catchment basin to which the channel is contiguous; it is direct in course, leading southward, and plainly has the marks of vigorous initial development.

(4) East of Sempronius the thickened drift indicates a long halt of the ice. Extending southward from this area, in which Fall Creek now heads, are several clean cut channels indicating the work done by ice-front drainage.

(5) In the region of thickened drift north of North Lansing I have also observed waterways that obviously are not due to postglacial erosion.

Ice-Walled Channels.

Gilbert[37] and Fairchild[38] have described the peculiar terraces and benches produced by water courses, one wall of which was the ice in position. The recent work of Fairchild in the Mohawk valley[39] calls attention to a variety of such water courses.

A few instances of these ice-walled channels are noted on the Moravia quadrangle. The development attained is not marked since in the higher altitudes of this sheet no water bodies persisted any great length of time. Where a rock slope abutted the ice, and the ice fed around this slope in either direction, the topography otherwise forming the conditions for ponded waters on either side, then as the ice retreated the water on one side or the other would coalesce or flow down into the other body. The channel through which the water spilled consisted of rock on one side and ice on the other. If the ice were permanent for some time, normal

[37] *Bull. Geol. Soc. Am.*, vol. 8 (1897), p. 285.

[38] *N. Y. State Mus.*, *22nd. Rep.* of State Geologist (1902), pp. r23–r30.

[39] *Ibid.*, *21st Rep.* of State Geologist (1901), pp. r35–r47.

methods of erosion would incise the rock slope, and a resulting bench and terrace would now indicate the course of this former overflow stream.

Where the highway leading southeastward from Moravia to North Summer Hill skirts the southern slope of the rock salient facing Montville we note at about the 1200-foot contour, the first evidence of one of these former stream courses. The appearance from the highway, however, is not suggestive of such a channel, but a short walk northward around the face of the salient leads one to a more conspicuous development of the former stream course. This point of overflow obviously taken by the water held in the valley eastward towards Morse Mill succeeded a higher channel which led the ponded waters about the brow of the hill and formed a conspicuous cliff and terrace extending about the prow and the southeastern part of the slope fairly parallel with the 1340-foot contour. Southward from this highway the course of the channel last traced drops, and at about one-quarter of a mile from the road it may be traced for some distance where it has smoothed out the morainic topography that characterizes the northern slope of Dry Run valley. Likewise, about one hundred feet lower in altitude may be traced the continuation of the first mentioned channel.

On the southern wall of Dry Run valley there is noted a marked over-steepening, not due to any lithological irregularity in the salient, which here is included within the district encompassed by a highway extending to the east and another extending southward and then eastward. The case of a deserted stream course here, while apparent, is not so clear as in the two just described.

The western slope of the hill south of Asbury is conspicuously free of drift, a condition due to the sweep of waters from the north between the ice and this hill. No pronounced bench was developed, but the rock over quite a width and vertical range has been fairly well cleared of glacial rubbish.

The slopes of many salients found on the east wall of Fall Creek valley also bear benches probably due to a similar cause. It is seen from the topographic map that this area is cut up by frequent and wide valleys, thus producing a medley of salients between which impounded waters escape successively to the lower levels, and in doing so, being held against the slope by ice, have channeled the rocks in varying degrees. I have not mapped these since in

no case do any of them present a linear extension of more than a few rods.

Drift of an Earlier Ice Invasion.

Positive evidence that the region included in the Moravia quadrangle was glaciated previously to the Wisconsin invasion was not found in this investigation. No contact between drift of different ages has been noted, neither have I observed individual deposits which suggest drift older than the Wisconsin. The strongest suggestion of any earlier glaciation is the presence of apparent interglacial drainage lines.

In spite of the lack of direct or positive evidence of the existence of an older drift sheet, in all probability this region was glaciated once at least previous to the Wisconsin invasion. Several lines of indirect proof point to this conclusion.

The work of Leverett,[40] Salisbury,[41] Woodworth,[42] Fuller,[43] Clapp,[44] and others[45] along parallels both east and west of the Finger lake district gives cumulative evidence of the existence of drift older than the Wisconsin. Knowing that ice of an Illinoian or some older sheet reached into southern New England and across Long Island into New Jersey, and that drift classified as Kansas has been found in northwestern Pennsylvania, the chance that the plateau section of New York state escaped glaciation contemporaneous with the ice depositing such drift in those areas is indeed slight. Indirectly, then, we infer that the presence of older ice on both sides of the Finger lake region and farther south implies that this region itself was covered by that ice.

The amount of erosion accomplished in these Finger lake valleys suggests, according to Tarr,[46] more than one ice-invasion. In acounting for some of the hanging valleys he alludes to the

[40] *Monograph*, xli, U. S. Geol. Survey (1902), p. 228.

[41] Geological Survey of New Jersey, *Annual Report for 1893*, pp. 73, etc.; vol. v (1902), pp. 187–89, 751–82.

[42] *N. Y. State Museum, Bulletin 48* (1901), pp. 618–70.

[43] *American Geologist*, vol. xxxii (1903), pp. 308–12.

[44] *Bull. Geol. Soc. Am.*, vol. xviii (1908), pp. 505–556.

[45] A. C. Veatch: *Jour. of Geol.*, vol. xi (1903), pp. 762–76. L. H. Woolsey: *Beaver Folio*, no. 134 (Penn.), U. S. Geol. Surv. (1905), p. 7.

[46] *Am. Geol.*, vol. xxiii (1904), p. 284. *Bull. Geol. Soc. Am.*, vol. 16 (1905), pp. 239–40. *Jour. of Geol.*, vol. xiv (1906), pp. 20–21. *Pop. Sci. Monthly* (May, 1906), pp. 392–93.

probability of multiple glaciation. "Through valleys"[47] offer equally pertinent hints of repeated ice-invasions.

Possible evidence of an earlier invasion is indicated also by the scattered hints of ice-dammed lakes older than the lakes held up in front of the retreating Wisconsin sheet. No data is available for a more accurate time-definition; the lakes may have skirted the front of the advancing Wisconsin ice; they may mark the advance or retreat of an earlier invasion. The shore lines of these older lakes so far as traced show discrepancy in attitude when compared with the shore lines of the more recent ice-front lakes. It is obvious, furthermore, that every ice-invasion of this Finger lake region witnessed the growth and decadence of such lakes. The strength of shore phenomena developed by the static water bodies characterizing the progress or retreat of any ice-sheet has a direct connection with the duration of the halt which occasioned the static body of water. If, therefore, the ice-dammed lakes in this region held up, for example, by the Illinoian ice-invasion had a duration comparable with the Wisconsin Lake Warren, it is probable that shore lines would have been developed that might locally withstand even one or more later ice-invasions and be observed today. Such phenomena have been tentatively studied in the valley of Lake Keuka;[48] if found in other of the Finger lake valleys, correlating data may aid in arriving more closely at the time of their origin.

On the supposition that this area has been glaciated previous to the Wisconsin invasion, we may consider the effects produced on an older drift sheet by another incursion of ice. These effects would be controlled somewhat by the topography, and to a much less degree by the length of the interglacial period. The drift which accumulated in transverse valleys obviously would suffer less through a second invasion of ice than would the glacial deposits made in longitudinal valleys. For this reason, then, older drift sheets should be better preserved in valleys transverse to the line of movement of the later ice-invasion. The bearing that the length of the interglacial period has on the question arises through the amount of soil that would be developed in the lapse of glaciation, and also in time through which the till already

[47] The designation used by Tarr, *Bull. Geol. Soc. Am.*, vol. 16 (1905), p. 233.
[48] F. Carney: *The Am. Jour. of Sc.*, vol. xxiii (1907), pp. 325–335.

deposited would have for induration. A drift sheet when undisturbed through two time units would assume a stage of induration that would not be reached by a drift sheet in one time unit. While the condition of induration attained by the till would but slightly control its resistance to the abrasive powers of another sheet, it is apparent nevertheless that the factor has some weight.

All evidence points to the conclusion that throughout this part of the Allegheny plateau the Wisconsin ice-sheet was vigorous. The erosion which it is assumed has been accomplished in rock valleys would very evidently accomplish work of the same degree on a till sheet previously deposited in those valleys. It follows, then, that a pre-Wisconsin drift sheet in this region must have suffered much from the influence of a later invasion. The older drift in the longitudinal valleys especially must have been largely removed, and in semi-protected areas suffered much disturbance.

The vigorousness of the Wisconsin ice is evidenced by the great mass of its morainal deposits. Thus while this last ice invasion did much destructive work on a till sheet already in this area, at the same time it produced rubbish which now doubtless buries much of this older drift.

A second invasion would also evidently affect previously deposited drift which escaped removal in bringing about in such old drift a condition of more or less complete induration. This is accomplished entirely through the weight of the over-riding ice. While I have not seen in the Moravia quadrangle any sections of drift which suggest an indurated condition, nevertheless the reports of well drillers in the region are very suggestive of the existence of such hard till in many widely separated parts of the quadrangle. It is entirely possible that this hard bluish till was deposited by the advancing Wisconsin ice; the final interpretation must involve its study over a wider area. My purpose is to record the fact of its general distribution in the Moravia sheet.

All the evidence here offered as bearing on the question of a possible pre-Wisconsin drift sheet is found in well records. I will accordingly refer to some particular localities where the drill has revealed the presence of hard blue clay. I appreciate the misconceptions that drillers often have of the material through which their drills pass, yet we must grant that in the presence of cumulative evidence of such indurated bluish drift there must be something in common with these wide-scattered deposits:

(1) About two miles south of Moravia Mr. J. C. Rounds sunk a well which shows 75 feet of blue clay. This well lies north of the first valley loop proceeding southward from Moravia. It is in the valley bottom, and the water flows with some activity from the pipe. While details as to the depth and other material passed through in this well are lacking, the certainty expressed as to the thickness of the blue clay is given as the writer had it.

(2) Directly north of the Lansing overflow channel, wells found along the east-west line approximately on the 1200-foot contour report several feet of blue clay.

(3) At Locke there are several wells, some of which flow, and all of which give a record of blue clay. That of Burdette Robinson, who lives a quarter of a mile southwest of the village, shows 160 feet of blue clay overlain by six feet of gravel. That of C. E. Parks just across the highway shows 170 feet of blue clay overlain by 10 feet of gravel. North of the village a short distance A. A. Slocum has a well which gives 80 feet of blue clay beneath some four feet of light-colored clay. All of these wells reported gravel beneath the blue clay. In the part of the Moravia-Locke valley where these wells are located there is evidence of slight glacial erosion by Wisconsin ice. At this point the valley divides; the western arm bottoms in rock not far from the wells; in the eastern branch a well one mile distant gives rock at 96 feet. Overdeepening which characterizes the main valley a few miles north is absent here. We would expect it to be absent near the point where the longitudinal valley divides because the salient of rock between the two lesser valleys protects that portion of the major valley near its base from ice-erosion. Hence the presence here of drift older than the deposits made by the retreating Wisconsin ice is not improbable.

(4) On the uplands north and east of Groton the wells with very few exceptions show several feet of blue clay.

(5) About a half mile east of Jones Corners a well shows 60 feet of blue clay beneath twelve feet of gravel. This is on the farm of George Barrows. At the Summer Hill creamery a driven well shows 28 feet of blue clay beneath twelve feet of gravel.

(6) Several wells about a mile and a half southeast of Peruville give a record of blue clay.

(7) On the property of John M. Sherwood, one mile west of McLean, is a well which revealed forty feet of blue clay beneath

sixteen feet of gravel. Gravel also underlies the clay. The well of D. W. Rowley across the highway has a similar record.

Obviously there are apt to be several lines of discrepancy in these well records because in all cases they were given the writer from memory. I place slight value on the number of feet of clay or other material alleged in the wells. The constant report, however, of an exceedingly hard horizon is suggestive of an indurated drift which may imply much antiquity.

ACKNOWLEDGMENTS

This investigation was begun some years ago at the suggestion of Professor R. S. Tarr to whom I am deeply obligated for sustaine encouragement and invaluable aid. Doctor J. B. Woodworth of Harvard kindly read the manuscript, making many important suggestions; and Professor Earl R. Scheffel of Lawrence college has rendered me great service in reading the proof.

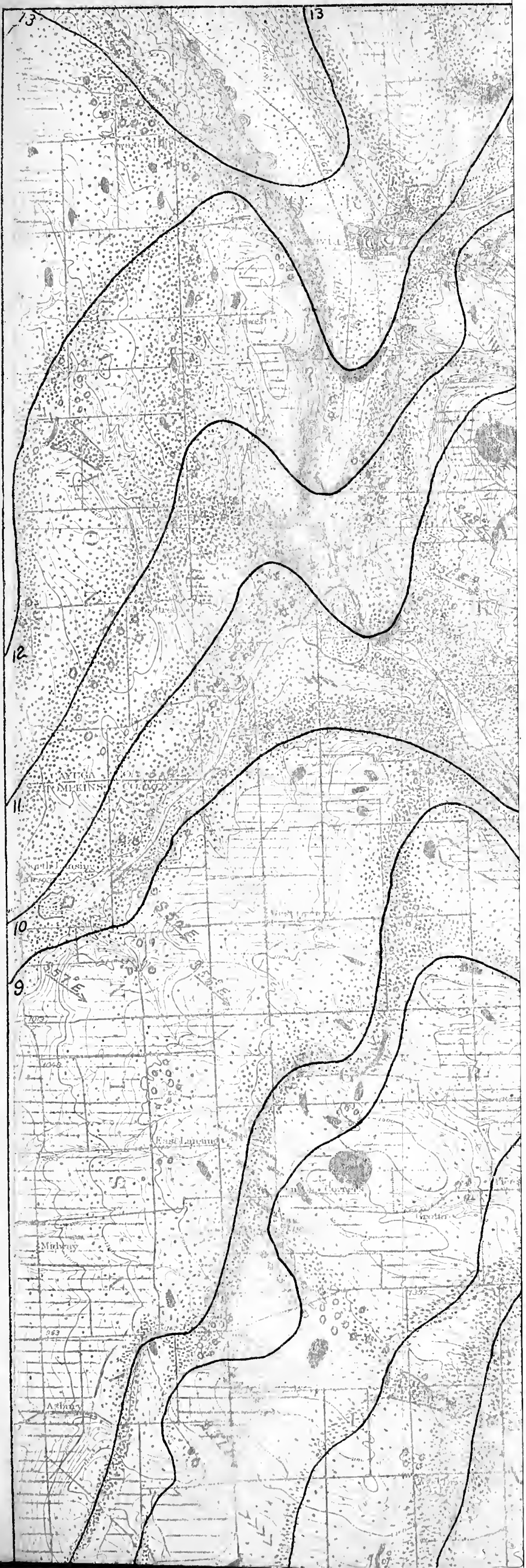
Plate XII. A Pleistocene Map of the Moravia Sheet.

The overlay gives hypothetical retreatal positions of the ice-front as suggested by the moraines and their valley loops.

The direction of striæ represent in each case the average of many readings.

The eskers are numbered, 1 to 9; and the deltas are marked by the letters, A to J.

In all other particulars the legend is indicated on the margin of the plate.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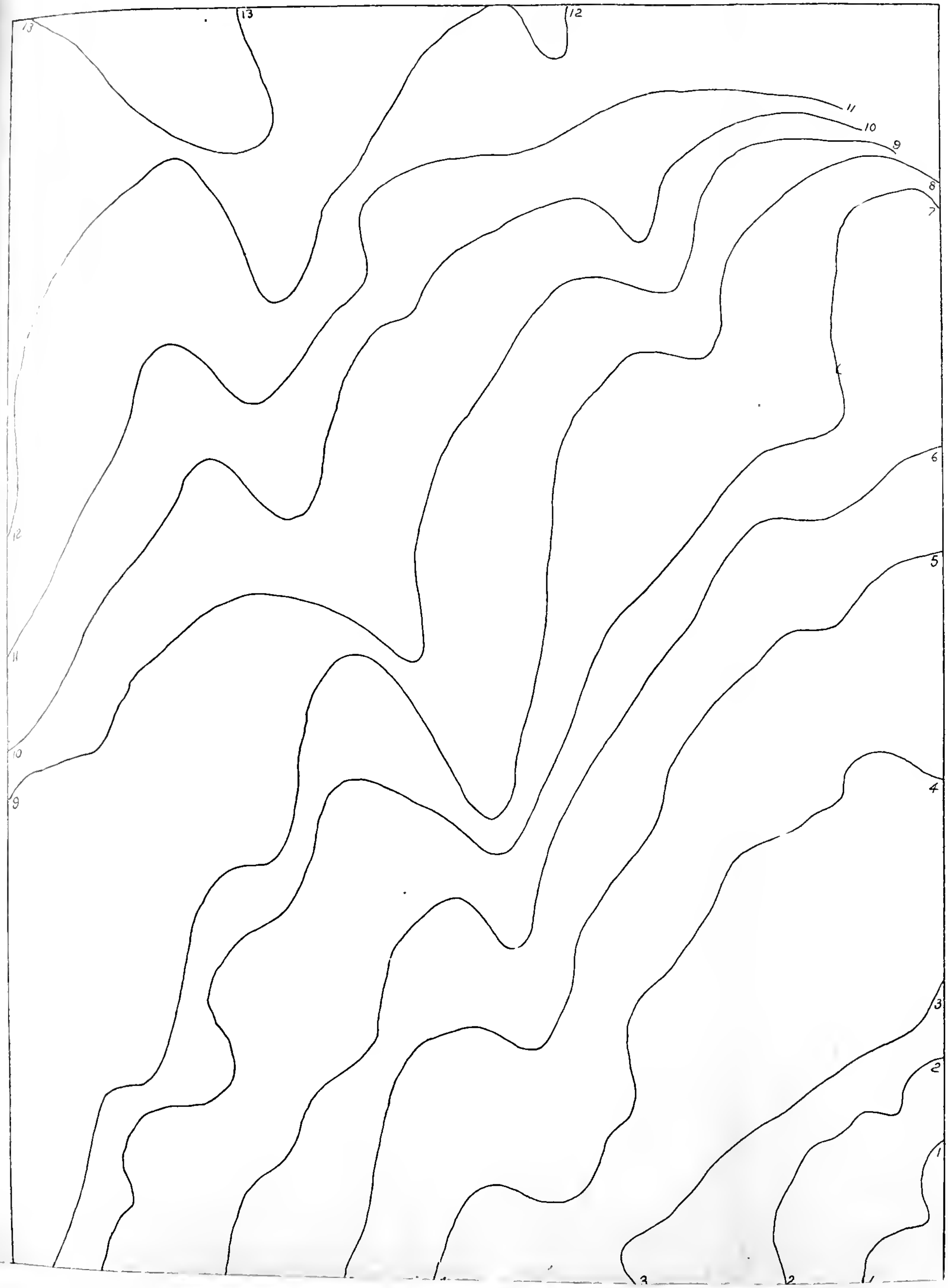

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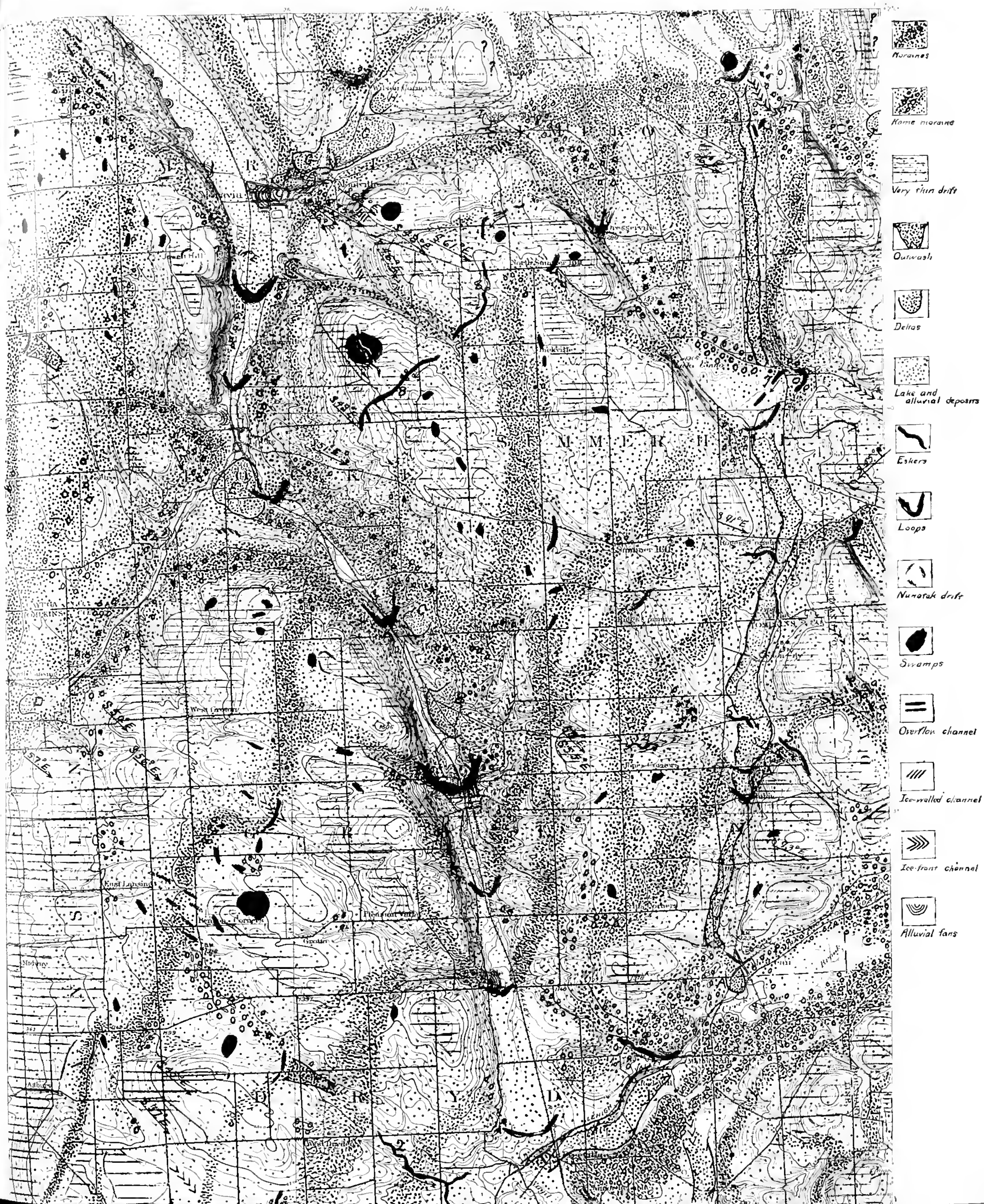
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Outwash
Deltas
Lake and alluvial deposits
Eskers
Loops
Nunatak drift
Swamps
Overflow channel
Ice-walled channel
Ice-front channel
Alluvial fans

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[Bibliographical names are in caps]

BULLETIN

OF THE

SCIENTIFIC LABORATORIES

OF

DENISON UNIVERSITY

Volume XV Pages 1-100

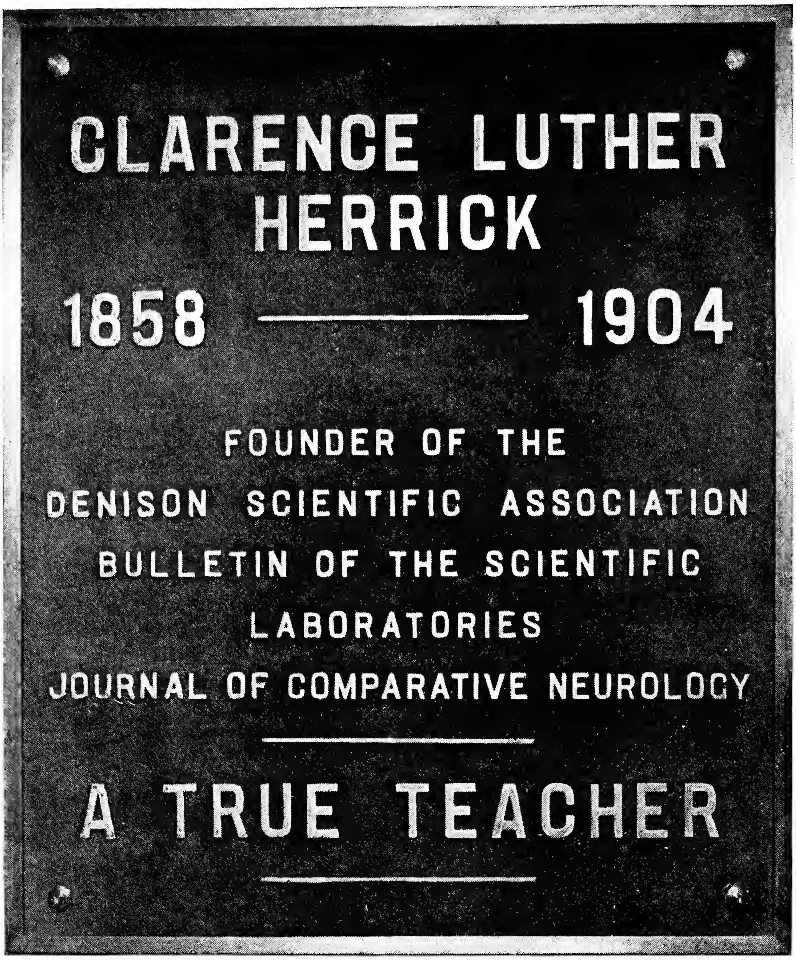
EDITED BY

FRANK CARNEY

Permanent Secretary Denison Scientific Association

This volume is published in commemoration of the twenty-fifth anniversary of the election of Clarence Luther Herrick to the Professorship of Geology and Natural History at Denison University

GRANVILLE, OHIO, MARCH, 1910



MEMORIAL TABLET

UNVEILED IN BARNEY MEMORIAL SCIENCE HALL, NOVEMBER, 1908

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CONTENTS

THE METAPHYSICS OF A NATURALIST

Philosophical and Psychological Fragments by the Late C. L. Herrick

INTRODUCTION

In these days when philosophy is considered less and less as transcendental metaphysics and more and more in terms of the instrumental methodology of the sciences, the thoughts and writings of men who represent this phase of human endeavor are coming to be valued above every other source of philosophical inspiration, The opinions of such men as Tyndall, Huxley, Helmholtz, Kelvin, Mach, Ostwald, to mention no others, become of great significance to philosophy when the latter is conceived as an interpretation and criticism of the underlying principles and methods of the sciences.

It is as a contribution to this increasingly valuable literature that these pages are offered to the public. Professor Herrick was not only an eminent naturalist and neurologist, but from the first he conceived and executed his researches in a philosophic spirit and with the special problems of psychology in mind. This fact in itself would make his views of interest. But when to this the fact is added that his ideas are always expressed vivaciously and in suggestive form, his writings become doubly interesting and important.

An account of the life and work of Prof. Clarence Luther Herrick, with portrait and an appended bibliography, may be found in the *Journal of Comparative Neurology and Psychology*[1] and more fully in the Bulletin of the Scientific Laboratories of Denison University.[2] As a young man, while serving on the Geological and Natural History Survey of Minnesota, he acquired a thorough and broad knowledge of natural history, devoting himself to paleontology, systematic zoölogy and comparative anat-

[1] Vol. 14, no. 6, November, 1904.

[2] Vol. 13, pp. 1 to 33, January, 1905.

omy. The suceeding five years were devoted chiefly to geology, and the later years of his life to neurology, comparative psychology and philosophy. At the beginning of the latter period he founded in 1891 the *Journal of Comparative Neurology and Psychology*, which he continued to edit until his death. His interest in philosophical questions was perennially active, as shown by the note-books which he made as a college student, his correspondence throughout life, and his frequent contributions to the psychological and philosophical serials.

Professor Herrick, though a great admirer of Lotze, whose lectures on psychology he translated and privately printed while still a young man for the use of his classes (with, significantly, an appended chapter on the structure of the brain),[3] was a disciple of no school. The systematist, he remarks in the introduction to one of his unpublished works, may be horrified to observe that questions of psychology and of neurology jostle problems of ontology and "Erkenntnistheorie." The hysterical individual, on the other hand, who finds the word system insupportable, will doubtless do well to stop here and may as well detain his fellow who sees in an unclassified fact a maverick escaped from the herd to be roped, rounded up and branded Hegelian, Herbartian, etc., as soon as possible.

The pages which follow were assembled shortly after Professor Herrick's death in 1904 from a large collection of miscellaneous papers. The greater part of this compilation was done by Prof. H. Heath Bawden, an arduous labor, very skillfully and sympathetically performed as a tribute from a pupil to the memory of his first master. The entire manuscript has been critically read by Dr. George Fitch McKibben whose association with Professor Herrick began when they were students in Germany.

The attempt has been made to correlate the most distinctive of the philosophical and psychological teachings of Professor Herrick by bringing together the important ideas scattered throughout his published writings and contained in hitherto inaccessible papers and unpublished manuscripts which it has been our privilege to consult. The greater part of what here appears is published for the first time, references being made to his published writings only so far as has been necessary to give the proper

[3] Published at Minneapolis. Pp. x + 150, 2 plates, 1888.

setting to this new material. The section on the theory of pleasure-pain alone contains any considerable amount of previously published matter and this is presented first in order to illustrate the nature of the data upon the basis of which the theory of consciousness and some other philosophical sections were elaborated. The chapters which are here assembled were not, however, prepared by the author with reference to each other, and this accounts for the large amount of repetition, which the editors have not attempted to eliminate.

A certain amount of interpretation and evaluation has been inevitable because of the fragmentary character of much of the material and because of the unelaborated state of many of the ideas themselves. But it has been the aim as far as possible to let Professor Herrick speak for himself.

In explanation of the heterogeneity and very unequal value of these chapters, attention should again be called to the fact that no one of them represents a finished product, and the parts were written at widely different times under exceedingly various conditions. Some of the most valuable passages have been extracted from personal letters. Others are taken from fragmentary pencil notes made when he was too ill to write more than a few minutes at a time. Some are sections extracted from partially elaborated drafts of systematic treatises. His papers contain outlines of four such books. Parts of two of these were quite fully written up; but very little of the others had been written.

He had in preparation a philosophical treatise and published some extracts from this work in the philosophical serials shortly before his death; others were published immediately thereafter. The earlier chapters of the present volume (except the first) have been drawn largely from the unpublished materials for this work. The later chapters are assembled for the most part from the notes for a text-book on ethics, to be entitled, *Lectures on Conduct: The Principles of Ethics from the Dynamic Point of View.*

These fragments suffer, not only from their hasty preparation and lack of revision, but also from the absence of the setting within which they were elaborated in the author's mind. Doubtless in the light of current criticism many details of psychological or philosophical exposition would be stated differently by the author if he were writing today. But the value of these papers

is quite independent of these considerations; it lies rather in the insight given into the workings of a philosophically acute mind unusually richly furnished with the concrete data of scientific observation.

In 1885 Mr. Herrick was elected Professor of Geology and Natural History in Denison University, and in the course of the year following this appointment he founded the Denison Scientific Association and established the BULLETIN OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY as the organ of publication of this association and the exponent of the scientific life of the college. On this, the twenty-fifth anniversary of his professorship, the Denison Scientific Association sends forth this volume, containing some of the fruits of Professor Herrick's ripest thinking, in the belief that by the dissemination of his own words it can best honor the memory of its founder.

THE EDITORS.

THE SUMMATION-IRRADIATION THEORY OF PLEASURE-PAIN

Professor Herrick's theory of pleasure-pain is significant in that it states the physiological mechanism of tension and readjustment which are required by the James-Lange theory of emotion, especially in its revised form as stated by Professor Dewey and Professor Fite.[4]

There is no separate apparatus for feeling. With each act of the conscious organism there are changes of tone comparable to the accessory vibrations constituting the timber of a musical instrument. These are associated with vascular changes (variation in the pressure of the blood in the capillaries and probably in the brain). The disturbance of equilibrium in these and other ways produces the change in feeling tone, varying from mere somatic feeling to the explosive excitement of certain sense irradiations.

All sensations are experienced as pleasurable in proportion as they relieve existing strain or overcome resistance; as painful in proportion as they fail to relieve such strain or overcome accumulated resistance. In other words, pain means congestion, contraction, obstruction, disadaptation, a disproportionateness of stimulus to the conveying power of the organ. Pleasure means diffusion, expansion, irradiation, discharge. In both cases there is summation of stimuli, but in the case of pain this summation finds no overflow or discharge, or the process of inhibition is carried to the point where the subsequent discharge results in a further mal-adjustment.

"Often an interval of one or two seconds may elapse after the sensation is perceived before pain appears. These cases, so often quoted as proving the distinct nature of pain, are in one respect fallacious. When a nerve fiber is penetrated by a pin the pain is nearly, if not quite, as promptly felt as the touch. When the finger is struck by a hammer the pain is frequently long delayed. But the acme of pain in that case is

[4] Cf. James, *Psychology*, vol. 2, p. 451; *Psychological Review*, vol. 1, 1894, p. 516; Fite, *Psychological Review*, vol. 10, 1903, p. 639; M'Lennan, *Psychological Review*, vol. 2, 1895, p. 466.

due to a reactionary process in the tissues, notably the vascular contractions. There may be several oscillations of pain and a set of summations of a curious character. It is even possible by bringing to bear counter-irritants, to preclude these after-effects and mitigate the pain, as by rubbing or pinching the part." "In the case of a burn the conductivity of the tissues and vascular responses are even more evident, and such attempts to differentiate pain from sensation as a modality of feeling are futile. The fact that there may be analgesia without anæsthesia, and vice versa, is tentatively explained by the recent suggestion, that thermic and painful sensations find their way to the cortex through the gray matter of the cord instead of the fibrous columns, and affords us added data for the generalization for which we are now ready, viz: Feeling is always composed of two sets of factors, first, a sensational element, and second, a cognitive element. The sensations which directly participate in feeling are non-localized (general or total sensations), or are so acute as to irradiate, and thus ally themselves with total sensations. The cognitions are primarily such as identify the subjective state with the empirical ego.[5]

I. Feelings.	Sensations.	Sense gratification and pain.	General or Total Feelings.
II. Occasions.	Normal (moderate) sensory stimuli.	Super-normal stimuli, with tendency to irradiate.	Diffuse (somatic), especially "total" stimuli.

"Bodily changes follow directly the perception of the exciting fact, and our feeling of the same changes as they occur is the emotion. Objects excite bodily changes by a pre-organized mechanism, and these changes are so indefinitely numerous and so subtle that the entire organism may be called a sounding-board, which every change of consciousness, however slight, may make reverberate. Every one of the bodily changes is felt acutely or obscurely the moment it occurs."

"Emotion consists (1) of general sensations of total, organic, or irradiating varieties which have in common a lack of localization and, as a result of associational laws, are amalgamated more or less closely with the empirical ego; (2) of more or less explicate or implicate cognitions (perceptions, intuitions) of the relation between the cause of the sensation and our well-being; (3) the emotion is more or less closely attached to various impulsive expressions which tend in various ways to intensify the two preceding. More in detail: The sensations are produced in

[5] This, and most of what follows, is taken from "The Physiological and Psychological Basis of the Emotions," *Wood's Reference Handbook of the Medical Sciences*, vol. 9, 1893, Supplement, p. 270.

most cases by vaso-motor changes which, in turn, produce 'total sensations,' usually entirely unlocalized and not necessarily distinguished apart from the feeling. Such sensations may be recognized and to some extent analyzed, by practice. They precede the emotion proper and compose its sensational element. When one lies half asleep in the morning and a loud report startles him, the sudden surging of the blood to the periphery produces a familiar but indescribable sensation, which may include tingling at the finger tips, a curious twinge in the axils, a suffocating sensation in the chest, as more specific accompaniments. Then a flash of fancy depicts the burglar in the kitchen and a scene of bloodshed, danger to self, and the like; now perhaps a strange 'gone' feeling in the abdomen, and helpless atonic condition of muscles follow; then impulse dominates, and the tendency to spring to the defensive arises; all this before judgment announced that the cook has slammed the range door. Granting that the illustration has served to indicate the meaning of the statement above, it need require but brief experiment and self-observation to show that vaso-motor and organic changes always accompany and afford a sensational basis for feelings. . . . . It is then no

Emotions.	Impulses.	Sentiment.	Disposition.
Somatic changes occasioned or accompanied by cortical activity.	Reflexes excited by somatic and cortical activity.	Persistent cortical changes.	Reactions of cortical residua or new data of consciousness.

mere figure which localizes the emotions in the heart or bowels, but a statement of sober physiological truth. A heartless man is one whose intellectual appreciation of the results of an act does not awaken sympathetic thrills in his physical being adequate to quicken in him a participatory or sympathetic state."

"The sensational elements in emotion are, first, pains and sense gratifications; second, obscure organic and total sensations which are not usually perceived as such, but are interpreted as part of the feeling; third, reproduced pains or gratifications always followed or accompanied by total sensations; fourth, representations which awaken by association either reproduced pains and gratifications which, in turn, give rise to total sensations, or the latter without the former; fifth, instincts which obey laws of association whose rational explanation lies in the development or phylogenetic history."

"Pain and sense gratification are more difficult to construe, because more direct and simple than the others named. So long as pain, etc., were regarded as simply exaggerated forms of ordinary sensation the problem was insoluble. That this is not the case is suggested by the fact that they pursue other courses in the cord, and are associated more

closely with thermic sensations. If a small area of the skin is isolated it is found that tickling with a feather is interpretated as warmth, and a thrust with a needle cannot be distinguished from heat. In other words, if the local signs by which position is recognized are excluded, the differences break down. It may be noted that general changes in temperatures states are closely connected with the general feelings, as witness a shudder or the cold chills of fear, and the glow of pleasure. Briefly stated, the peculiarity of pain and the intense gratification of sense which adapt them to become sources of feeling, is their diffusive (irradiative) character. If the current suggestion that algesic stimuli pass by conduction through the gray matter of the cord be substantiated, a much closer connection with the visceral centers than hitherto suggested may be postulated, and the thrill of pain can be readily interpreted as the sympathetic contraction wave passing throughout the vascular system. The evidence for the existence of adequate vaso-motor causes of the sensational element in emotion is largely subjective, but those familiar with nervous diseases will not lack for evidence that variations in circulation are powerful factors in emotional disturbances. . . . Flushes of cold and heat; tingling and palpations local and general; gusts and torrents in the blood; creeping, swelling, scintillation of the skin; giddiness and elation—these and indescribable 'all-over' sensations are easily separable from the intellectual appreciation, which may even be absent; and one may be a wondering spectator observing the irrational gyrations of his own sense to tintinnabulating stimuli upon which judgment turns the cold shoulder. Another class, afforded by the tickling and shuddering or irradiating sensations proper, further illustrate the necessity of diffusion in emotional sensation. The slight sensations of tickling, aided by subjective modifications, extend in most varied and irresistible sensations over the whole body. Its emotional character is almost wholly apart from the intellectual element. The shudder and chill which spring from a gritting sound or the velvety touch of a peach, imply in addition considerable instinctive elements."[6]

The mechanism of the process of irradiation has been investigated by Professor Herrick (following Dogiel) in the case of certain vascular epithelia (especially in the sexual organs) whose excitation is connected with some of the most intense pleasurable experiences.[7] Association tracts in the cortex illustrate the mechanism of irradiation in the case of the higher affective processes where the revival of residua plays an important part.

[6] *Reference Handbook*, pp. 270–272.

[7] See references in Baldwin's *Dictionary of Philosophy and Psychology*, article "Irradiation" and cf. *Journal of Comparative Neurology*, vol. 7, p. 155 (March, 1898); vol. 2, 1892, pp. 111–114; vol. 5, 1895, pp. 1–32. For an illustration of the type of diffuse peripheral nerve plexus here referred to, see Herrick and Coghill, *Journal of Comparative Neurology*, vol. 7, p. 32–53 (July, 1898).

The most localized forms of pleasure are accompanied by a peculiar nervous diffusion, as in tickling and the genial effect of warmth. This effect is known as irradiation and is also characteristic of higher states of pleasurable feeling. Both pain and pleasure depend on exalted stimuli, but the reaction of the system toward the stimuli largely determines their pleasurableness or painfulness. The same excitation may excite one or the other feeling at different times.[8]

This last statement contains an important thesis of the doctrine, namely, that summation or irradiation is painful or pleasurable only under certain conditions of intensity. As in the general statement of the equilibrium theory of consciousness of which this is a corollary, the condition of pain and pleasure is a state of *relative* tension or equilibrium. If pleasure meant merely ease of adjustment and pain difficulty of adjustment, then habit would carry with it the greatest pleasure and pain would be in direct ratio to the difficulty of adjustment, neither of which is uniformly the case. Up to the limit of normal functioning only, does pleasure increase with summation and subsequent irradiation. Beyond this point pain supervenes. It is only the relatively free discharge that is pleasurable. Supernormal irradiation is painful as well as supernormal summation. The limits vary from individual to individual. But the general principle holds that when the summation or resistance lies between certain limits of intensity determined by the structure and inheritance of the organism, the subsequent discharge or irradiation is pleasurable; if the summation is below or above these limits the discharge is painful. The apparent incompetence of the theory to explain "the pains of negative states, as ennui, etc., is only apparent. Whether a stimulus is painful or not depends not on the absolute intensity of the irritation, but on the capacity of the mechanism to transmit it. In ennui the sluggish system is incapable of reacting against the slight stimuli and their monotonous character causes a summation and intermittent discharge."[9]

Sensation differs from feeling in the more definite localization of the stimulus, either by eccentric projection upon the periph-

[8] *Journal of Comparative Neurology*, vol. 5, p. 18 (March, 1895).

[9] *Journal of Comparative Neurology*, vol. 5, 1895, p. 212. See also article, "Summation," in Baldwin's *Dictionary of Psychology and Philosophy*.

ery of the organism or by externalization of the object in the outside world.

"The finger resting on a rough surface affords a sensation of roughness referred to the object, but a feeling of disagreeableness or pain referred to the self.[10]

In common parlance no distinction is made. Experience is spoken of indiscriminately as sensation or feeling. And in fact they do not exist apart. But when this vague total sort of experience comes to be cognitively controlled, that is, when it comes to be more precisely localized and referred, we call it sensation rather than feeling. The sensation does not lose all affective tone but it is subordinated to the cognitive function.

"In general it may be said that the prominence of the feeling element is in inverse ratio to the perfection of the localization." "Those sense spheres in which localization is most pronounced are nearly or quite devoid of feeling." "There is much reason to think that the feeling element is a function of the extent of the lateral propagation of the stimulus in the centers while the sensation is the conscious product of the reaction upon the specific center. In the healthy body all normal stimuli as well as all responsive acts are calculated to produce pleasure, the amount of this enjoyment being dependent to a certain extent at least upon the range of irradiation or overflow of the excitement. Painful stimuli, on the other hand, are such as impose on the avenue of communication or organ of reception a larger burden than it can carry, whether because the excitement itself is too intense or by reason of some reduction in the power of the organ."

"The cognitive value of sensation, on the other hand, depends upon the series or system of brain centers called into play. No sensory impression passes directly from the organ of sense to the cortical center where it becomes conscious. Each sensation has an infra-cortical center where the materials from the sense organ are redistributed and combined with elements from the motor organs in the most complicated ways." "When a light falls on the eye and a definite change is produced in the pigment of the retina it must not be supposed that the resulting irritation of certain nervous end-organs is at once transmitted to the cortex to become the occasion of a sensation. On the contrary, the stimulus from the illuminated point passes to the coördinating apparatus in the quadrigemina where efferent currents arise and pass to the nuclei of the eye-muscle nerves and coördinating apparatus generally. After coördination the muscular effort involved in the coördinated act is registered; and this, with a variety of other acts below the level of consciousness, go together to the cortex and there affect the visual and other

[10] *Journal of Comparative Neurology,* vol. 4, December 1894, p. 226.

centers so that the net result is not that of 'blueness,' let us say, but that of a particular degree of a particular kind of blueness in a definite place. Upon the equilibrium theory of consciousness it is not difficult to conceive that the tendency to coördinate and fuse various stimuli into one form of activity must be perpetually present, and as a matter of fact the most striking peculiarity of mental action is this same law of mental composition which finds its highest expression in what is called apperceptive action."

THE EQUILIBRIUM THEORY OF CONSCIOUSNESS

Professor Herrick's theory of consciousness, which he frequently alluded to in his writings but which he nowhere systematically worked out, is bound up with his general view of the dynamic nature of the vital equilibrium and its relation to the special functions of the nervous system. The idea that the living organism is a moving balance of equilibrated forces is a familiar idea in recent theoretical biology, but this notion has not been extended in any thoroughgoing way to the phenomena of brain activity where structural and descriptive categories still hold almost exclusive sway.

"In no department of physical science is it so plain as in neurology that we are dealing wholly with dynamic elements. While it is true that in the structure of the brain we have to do with morphological details of marvelous complexity and the descriptive side of our work is concerned with the varying outlines, sizes, and combinations of cells, fibers, etc., and the still more recondite structures within the cells and their dendrites, yet it is always obvious that these morphological peculiarities are but the expressions of inner forces and their responses to others from without." "Correspondence in mode is the condition of identity implied by a dynamic theory, and the heterogeneity expressed in the forces of the body of a man may be expressed in the terms of the forces of a spermatozoön equally well. . . . . Does not the body preserve its integrity in spite of the flux of its materials? Why should not the actual materials of the nucleoplasm be in a similar flux while retaining its form, i. e., its dynamic attributes?" "We venture to suggest that there is no such sharp distinction between nervous functioning and the intracellular processes of the ordinary non-nervous cell as our present terminology and usage suggest." There is in the case of many lower types of organism "a form of vital equilibrium so resident in the general system as to give rise to much the same phenomena of nervous unity as in the case of higher animals." "It, then, may be supposed that the circuit of nervous action in any part of the body passes through a variety of smaller somatic circuits and that the spheres of the two forms of activity overlap so that the return nerve current bears the influence of this interaction. The nervous equilibrium is only a central specialized part of a vital equilibrium embracing all the activities of the body."[11]

[11] "Physiological Corollaries of the Equilibrium Theory of Nervous Action and Control," *Journal of Comparative Neurology*, vol. 8, pp. 21–26 (July, 1898). Cf. also "The Vital Equilibrium and the Nervous System," *Science*, June 17, 1898, n. s., vol. 7, pp. 813–818.

In an article on "Psychological Corollaries of Modern Neurological Discoveries"[12] Professor Herrick said that

"the condition of consciousness is not topographical but consists in the form of *activity*" (p. 155). "It is impossible to discover a specific portion or a definite *kind* of matter in which consciousness resides, for no complexity of the material unit could make intelligible the diversity in consciousness, while *any* complexity destroys the objective grounds of unity. It is equally hard to discover any physiological basis for the continuity of consciousness. The idea of consciousness as a property is accordingly abandoned and it remains to conceive of it as a *form of* energy. Pure energy with the attribute of spontaneity it could only be if it were in the mode of absolute equilibrium, in which its activities should be wholly reflected into themselves. This can only be predicated of infinite essence and it is necessary to substitute the conditions of *relative* equilibrium in a sphere of interfering activities. The last few years have revealed in the cerebrum a mechanism of neural equilibration of unsuspected complexity, and all that we have recently learned of the physiology of the nerve stimulus only emphasizes the belief that the whole of the cortical complex is adapted to react as a unit, though not as an invariable unit. The great extent of the system of associational tracts and the facility with which new channels of overflow are set up or marked out is additional evidence in favor of an equilibrium theory of consciousness. . . . . The conditions of consciousness consist in the proper equilibrium of stimuli to produce a reflection of the stimuli upon the complex of which they form a part. The mechanism of this condition is found in the cortical centers, which are in continual action in such a way that a vortex of activity is in continual flux—each element contributing to the balance of the whole. To this complex, external stimuli are continually being admitted, whether as separately unobserved elements from the general-sensation apparatus of the common sensorium (giving rise simply to the implicate concept of personal existence in space), or more specific stimuli through the avenues of the special sense organs. Every sense-content with its escort of reflexly-produced associated elements causes a more or less profound disturbance of the psychical equilibrium and the nature of this disturbance depends not alone on the intensity and state of concentration, but very largely on the kind of equilibrium already existing. . . . . The character of the conscious act (and the elements of consciousness are always acts), will of course depend upon the extent to which the several factors in the associational system participate in the equilibrium. Each disturbance of the equilibrium spreads from the point of impact in such a way that progressively more of the possible reflex currents enter the complex, thus producing the extension from mere sensation to the higher processes of apperceptive association. A

[12] *Journal of Comparative Neurology,* vol. 7, pp. 155–161 (March, 1898); cf. also "The Material Versus the Dynamic Psychology," *Psychological Review,* vol. 6, 1899, pp. 180–187.

conscious act is always a fluctuation of equilibrium, so that all cognitive elements are awakened in response to changes rather than invariable or monotonous stimuli" (pp. 155-157).

In the article on "Brain" in Baldwin's *Dictionary of Philosophy and Psychology,* Professor Herrick briefly states the theory as follows:

> The theory of consciousness which seems best to conform to the conditions of brain structure and its observed unity is that each conscious state is an expression of the total equilibrium of the conscious mechanism, and that intercurrent stimuli are continually shifting the equilibrium from one to another class of activities. In other words, the sensation accompanying a given color presentation is not due to the vibrations in the visual center in the occipital lobe, but to the state of cortical equilibrium or the equation of cortical excitement when that color stimulus predominates. Previous vestigial excitements and coördinations with the data from other cortical centers all enter into the conscious presentation. As the wave of excitation passes from the visual center to other parts, the proportional participation of other centers increases, producing a composite containing more distantly related elements (p. 135).

The widely current belief in the anatomical separateness of the neurones entering into this neural equilibrium accords well with the theory and in fact either such an anatomical or some sort of a physiological barrier to the free discharge of nervous impulses is essential for the explanation of some of the facts. The theories of retraction of the neurone under varying functional conditions are particularly attractive in this connection, the education of the nervous system also being conceived as involving the development of new functional pathways as new associations are acquired and the short-circuiting of the old ones as activities become mechanized. Many of the peculiarities of inhibition or resistance to nerve stimuli may be explained as the result of contractions of the functional processes of the nerve cells.

[But much more fruitful in this connection are the more recent physiological theories of interneural resistance, particularly the carefully elaborated doctrine of the synapse of Sherrington.—Editor.]

Whether or not the theory of retraction be accepted in its present form, it is important as an attempt to state a device for breaking and making the organic circuit necessary to conscious-

ness, though this probably should be conceived as a functional rather than as an anatomical discontinuity. If a chemical or circulatory theory contains the true factor for determining these transfers of energy, as seems now more probable, the preceding conception will have to be revised to meet the demands of the facts. But that some sort of dynamic interchange takes place at this point is made probable by the structure of the nervous elements and by many converging lines of evidence, whether the nerve cells be conceived as anatomically separate or as forming a continuous network as some eminent investigators believe.

According to the dynamic theory

> the act of consciousness is not the result of an excitation in any cell or cells, but is produced by the impinging of an æsthesodic[13] upon a kinesodic system in reciprocal reaction. The transmission of nervous force does not produce a higher force; but the peculiar interference or increase of tension of nerve forces in antagonistic equilibrium does. Consciousness depends on the dynamic element—a translation of force into energy and thus, *to us*, there seems to be a complete hiatus between consciousness and all other phenomena.[14]

The motor reaction (in at least incipient form) is essential. The vast majority of our acts are performed without the aid of consciousness. But

> even in cases where the subsidiary cortical current actually passes it may awaken no consciousness. This is explained upon a dynamic theory of consciousness. The cells are indeed excited by the current but, for whatever reason, no interference or kinesodic reaction is produced. Only when an antagonistic wave is set up is consciousness possible. This does not, however, prevent an unconscious process from awaking consciousness afterwards by vestigial action. . . . . Our judgment that part of our acts are unconscious means simply that the same sensory state is often combined with different amounts of kinesodic activities.[15]

The equilibrium theory of consciousness has to contend with a great obstacle in the form of a nearly universal popular fallacy. We have grown so accustomed to the necessity of localization of

[13] See Baldwin's *Dictionary of Philosophy and Psychology* for definition of these terms.

[14] *Journal of Comparative Neurology*, vol. 5, 1895, p. 212.

[15] *Journal of Comparative Neurology*, vol. 5, 1895, p. 213–214.

all outer experiences that the mass of non-localizable experiences has acquired the force of a negative localization—a state of not-outsideness, so to say, a subjectivity. The grouping of the not-outside and the relatively constant as the empirical ego on its two sides of feeling and volition has received much study of late and it becomes apparent that the old theory of a simple central sense of effort is far too sophisticated a concept. So long as it persisted, it was natural that a search for the "seat of the soul" should be protracted even after the spatial element had been quite analytically treated by Kant and Lotze. We are driven by modern psychology to Lotze's position that a thing is where it acts and the being in the same place as another means that the two things have the power of interaction. It is plain that for a thing to be in a place apart from reacting upon the determinants of that place-in-which would be an impossible state to know of, if it existed, and an impossible thing to construe ontologically.

Given the proper form of activity, and consciousness is given. It will make no difference whether this form is a neural equilibrium in the entire nervous system or restricted to the cortex. The cortex alone of the nervous structures appears to afford evidence of the arrangement securing the equilibration demanded, and for this reason it may take rank as an organ of consciousness *par excellence*.

The brain is a prodigious mechanism for bringing diverse stimuli together in one continuum in the cortex. So far from a device for projecting stimuli upon one point, as imagined by Des Cartes and most speculative philosophers, the stimuli suffer a sort of dispersion in their path toward the field of consciousness. I discover that this mechanism is in a terrific state of activity. Currents of blood and lymph supplying highly complicated currents of energy are passing through the mechanism continually and doubtless the energy actually operating in the brain, if convertible into gross forms of work, would lift many tons literally miles high daily, for we deal here with what the physicist would call intramolecular types of forces as well as molecular and molar types of forces. Now all this vast activity reveals itself to us in scarcely any commensurate return. Just as the spectator looking at the solar system would see little evidence of the energy expressed in the equilibrated system of planets, every molecule of which is brimful of activity in balanced con-

dition, so looking at the brain as a mechanism for mental work' we find it set on a hair-trigger, and a breath on an eyelash is adequate stimulus to liberate vast stores of readjusting energy.

All questions of the nature of sensation as well as of other mental activities hinge on the view taken as to the nature of consciousness. As consciousness is by its nature confessedly beyond the reach of analysis, we are forced by circumlocution to describe it in terms of its neurological concomitants. From many considerations, especially the structural coördinations and the unitary nature of consciousness, it seems most reasonable to conclude that the physiological basis of consciousness is the balance or counterpoise of the cortical stimuli.

From this point of view when the sensory stimulus is admitted to a cortical station there is at once a change of equilibrium—a setting of the neural excitement in the cells stimulated toward the rest of the cortical complex. This tide of nervous activity will obey laws of force, finding paths of least resistance, etc. The brain is so formed that it is possible for a great variation in the permeability to stimuli to exist at different times without any marked modification in the number or arrangement of the elements. It may be that the extent of the neurodendrites is the most important factor. It is known that the number and divisibility of these processes increases from youth to maturity. While they greatly increase the range of possible coördination (association), their presence may also serve to increase the total resistance and give rise to a sort of mental inertia. Most of the problems connected with sensation are connected with the content of sense and in reality belong to physiology and not psychology. Yet since the method used employs introspection in the study of this content, it may find a place in the psychological domain. The reason why one sense-content finds more ready entrance to the mechanism of consciousness in any given case may be found in the intensity of the neurosis, in the frequency with which its path has been before used (habit) or the state of equilibrium at the time existing in the cortex. If the neural tide is already setting away from a point of disturbance in the auditory center it will be somewhat more difficult to force a new wave from the visual center. The psychological study of sensation reduces to the study of the laws of association, and the great bulk of matter discussed under sensation is found to belong with the study of sense-content.

We must distinguish the content of sense from sensation.[16] Here is the source of great confusion. Too often the content of sense is confused with sense perception. The content of sense at any given time is the sum of the affections of the lower or primary æsthesodic centers. In the visual field, for example, it is the totality of the immediate central reactions corresponding to the retinal excitations. We may think of them as distributed over homologous parts of the optic tectum; but it is probable that we should add the effects of certain optic reflexes set up with their æsthesodic reactions, and not improbable that it will be necessary to include modifications or accretions due to changes in the cortical visual area; but as yet there is no sensation, only a sense-content. Besides the contents of special senses—vision, audition, taste, smell—there is the whole æsthesodic contingent from the spinal cord, many of which never become sensations normally but may be brought into consciousness under exceptional conditions. Some perhaps are capable of entering sensation only as a *quale* of some other, having no localizable tag suiting them to independent recognition or isolation. These, however, are just as real a part of the content of sense as the pre-sensational elements of color or pain.

Now it is evident to ordinary experience that in many cases the act of sensing a sense-content is really an act, not an occurrence. We fix that particular element. It is immaterial how we are impelled to the fixation. It is an expression of our spontaneity, a reaction of the subject. Many considerations justify us in supposing that an act of consciousness is a reaction of consciousness. There are, it is true, in the sense-content of vision focal and marginal impressions, but the physical mechanism is well known. There is something similar in the auditory field whose physical mechanism is obscure. There is nothing of the sort in the other senses except skin-sensation and there the physical origin is beautifully illustrated by the localization experiments. The localization apparatus of the senses has apparently suggested the theory of focal and marginal consciousness. We believe that a proper interpretation of experience removes the ground for this assumption. The various intensities of sense-impressions con-

[16] Cf. "Focal and Marginal Consciousness," *Psychological Review*, vol. 3, 1896, pp. 193–195.

stitute the basis for focal and marginal sense-contents. In like manner there is a perspective of vestiges presented to consciousness.

We may consider what the effect is when one or another content of sense is admitted to the "synsorium." If it is a single color (let us say) then the balance is disturbed in a given characteristic way at the moment of admittance. We perceive a color. If instead there is a retinal picture of a landscape, the equilibrium is disturbed in a different way, and one which produces its instaneous impression; but this is followed by the after-shower of innumerable vestigial impressions from the optic and other associated areas which each in turn affect the equilibrium of the synsorium. We insist that there must be in this ultimate mechanism of consciousness an absolute succession. A wave of consciousness with focal and marginal parts is inconsistent with any conceivable means of bringing sense-impressions to the æsthesodic and kinesodic systems of the cortex. Only so can intimate connection of various forms of innervation with perception be explained. The discussion of this point is difficult, and need not be attempted. Probably most psychologists will agree that consciousness is an act, not a state; and that it is a pivotal act which takes place in the very focus of our being. The unity of consciousness may be interpreted to mean that consciousness is only possible when the æsthesodic and kinesodic currents affect the equilibrium of the entire mechanism of consciousness. It seems possible to conceive of the situation as an instance of most complicated equilibrium where each element of the conscious mechanism (the synsorium) contributes its tension to the balance of the whole. However this tension is effected, a conscious state follows.

Of course we encounter a difficulty at this point. Has the soul any separate existence or is energy conceived simply as a sort of spring-board against which matter or force impinges? We answer that the transformation of forces produces real changes in the career of energy. Is it possible for energy in one form to react on energy in another directly? If we say "yes," it is natural to object that this reaction would produce resistance and so force. If we say "no," what becomes of a career of energy or the life of the soul. We must believe that there is no direct reaction of energy on energy—of soul on soul; but that the form

in which energy occurs will determine the nature of the reaction as force. If we admit that the energy of a conscious being is only a sort of *via inter quam,* we must insist that it is no homogeneous medium. In the mind the forms of reaction are complex and the forms of intermediary energy are also complex. The equilibrated forces of the organ produce a stream of highly differential energy by which new reactions are profoundly modified. Every translation of force is attended with production of energy, but the kind or phase of energy differs in accordance with the nature of the force. The complete synthesis of diverse forces of a special grade into homogeneous energy in a vital organism produces consciousness. There may be something corresponding in the case of every production of energy, but we cannot know it; for consciousness reveals itself only in self-consciousness. Self-consciousness is the result of reflected energy becoming reconverted into force. Will is the energy evolved in the higher sphere indicated.

Here is a difficult point. Transition from force to energy under suitable conditions is conscious and the energy so set free is *will.* Will is of a sort with all energy; it is spontaneous activity and only conditioned by its own form. It becomes our will only in self-conscious states. Consciousness is not a force but a *quale* of the will.

This was brought out somewhat more concretely by Professor Herrick in 1893 in the course of a critique of Münsterberg's "Die Willenshandlung," where he says:[17]

> Perhaps we have here precisely the difference between will and impulse that the former is 'reinforced by the *totality of our personality.*' It is certainly not the province of physiological psychology to enquire more closely into the nature of the ego, but it appears that this science may have incidentally and perhaps unintentionally done very good service to rational psychology by showing that there is no amphibious bugaboo between the conscious element and the voluntary motion. There is no mongrel will with head of Jove but whose tail executes fishlike and simply physical wriggles. For this much, thanks, and thanks too for the assurance that the will is born of the intelligent elements in our being and clothed with feelings. It is no isolated "faculty"—no poor third of a divided personality, but it is the whole ego in its direct expression, an

[17] "The Scope and Methods of Comparative Psychology," *Denison Quarterly,* vol. 1, Nos. 1 to 4, 1903.

expression which varies in richness and significance as the horizon of our experience widens (p. 279).

Looking again at the simple facts of sensori-motor response, it appears that we have neglected a most important point in the process when we say that the force is all returned, viz: that its *form has changed* and the nature of the change depends on the nature of the subject. We know that our responses to outward stimuli depend on the temporary as well as the permanent disposition of the organism. When a reflex circuit is opened, the response depends on the anatomical structure of the spinal cord. When an automatic circuit is opened, responses follow depending on complicated reactions of part on par . When conscious circuits are opened, the responses depend on whatever produces consciousness. Of course it will be replied that the structure of the organism is the product of previous stimuli, but that only carries us back a step or two. How organization is possible is just the problem. Organization is the formation of complicated states of equilibrium and all such states of equilibrium result in evolution of energy capable of changing the mode of force (as in our illustration of impinging bodies). These enormously complicated vortices of energy constitute the soul of the organism.

We have seen that activity is the sole element of experience, and its varying forms are, in a sense, the algebraic expressions for interactions. Consciousness is one of the coördinate expressions of the totality of activities of certain grades. The only condition of force in which no force is lost and yet a new mode is introduced, is equilibrium. It is natural to apply the same suggestion here. Flint met steel and a simple kind of force was translated into higher and back again. There was a flash. Trace the forces and weigh them; they are all there, but the fact of change is a fact of a higher kind not weighed in your balance. Applying the same reasoning to the mental phenomena, we see that the forces whose intermittent stream feeds the psychical lose nothing in their passage through the mind; the stream is undiminished, but there has been a transformation the peculiar form of which has been the essential psychical content. The mind may be compared to a registration apparatus which registers by strokes on a dial the passage of a certain quantity of fluid flowing through its chamber. Consciousness is a manifestation

due to a form of equilibrated energies, which particular type of energic equilibrium may only be reached after the amount of energy reaches a certain quantum. Only those forms of energy have consciousness which are adapted to converge and be reflected in harmonious modes.

Could we imagine a perfect mirror which reflected every surrounding object but was itself invisible, we might find it difficult to make out the qualities of the mirror, even though we became very familiar with the laws of reflection. The soul is such a mirror, and all the images which it produces are, so far as we can tell, reflections of physical phenomena.

BODY AND SOUL

The term "mental state" is as ambiguous and contradictory as the more comprehensive designation "mental faculty;" indeed, the latter is less open to criticism than the former. What we really have to do with is an activity or its absence. In the latter case there is a "state" of non-existence or of not-being. In the former case we have an unwarranted postulate. A state of activity implies a something apart from the activity which may at some other time be in a state of inactivity. But this assumption is gratuitous. Mind is not a something which can under suitable conditions get into "a state," and so produce this and that activity recognized as mental. The totality of the activities constitutes the mind.

But is there not a physical basis of mind of which these activities may be said to be states? What the physical basis of mind is it does not here concern us to inquire. Whatever this is, mind is not a state of matter. If one chooses to describe mind as one of the forms of the activities of matter, we shall have no quarrel with him if the same treatment be applied to the other so-called qualities of matter. When this is done, we have a collection of activities and nothing else. Common usage describes matter at one moment as something whose reality consists in its ability to be affected in certain ways by forces. What this property is which permits force to affect it we are not told. But plainly it is itself a disguised force, for it is able to alter the mode of force. At other times usage seems to assume that the properties of matter are forces. Without this assumption, it is impossible to treat of the phenomena of elasticity. It is evident that this whole field is clothed in densest obscurity and crudest ambiguity. It is necessary to accept one or the other basis of physical reality: (1) matter as a metaphysical generator of force, (2) force as a multiform expression of a spontaneous primal energy back of which it is impossible and unnecessary to go.

Everyday experience teaches us that there is a certain segment of our objective experience that has a closer relation to the *ego* than other portions. The child may offer to its toe a

portion of the cake it is eating with no recognition of a difference between this object and other living objects like the kitten with which it is playing; but it is difficult for the adult to avoid thinking of the body as an integral portion of self. The child also may weep because of a fancied injury to an inanimate object with an altruism of which the adult is incapable, and, on the other hand, we might imagine a state of being in which an injury to another or an ideal or ethical wrong would excite quite as deep response as a wound to the body. We know of the existence of the body as a mass of "matter" in the same way as we learn of the existence of other material bodies by the testimony of our externalizing senses; but in addition to this source of information we have the associated information from the partially or completely unlocalized feelings of pain and effort, etc. A blow on the toe is not only seen to take place, but the feeling of pain resulting is added; while even the tactile sense is so modified that it reports the sensation as subjective, *i. e.*, localized within the body rather than outside of it. We discover that this body is composed of a vast number of coördinated parts and do not fail to note that while the liver, for example, may be seen and felt, as any other portion of matter may be, yet in its state of coördinated or structural differentiation it has other functions—it secretes bile and stores glycogen, etc. Just as the tactile property is due to a peculiar arrangement of molecules whose essential nature consists in the putting forth of certain forms of activity giving rise to the resistance we feel, so the organization into the so-called structure of the organ is simply a revelation in a roundabout way of the fact that the coördination is carried further in progressively involved cycles till the result is the more obscure function of secretion. One of the processes is just as much a result of the structure as the other (and no more). It is a common practice to contrast the body, which is present to the senses, with the soul which is felt as the immediate product of consciousness. It is true that the soul is not independent of the body in our experience, but is distinctly associated with it and manifests itself in direct and indissoluble association with a special organ—the central nervous system. Materialistic psychologists have not hesitated to state that the relation between the brain and the production of thought is as direct as that between the liver and the production of bile. This is a some-

what revolting statement, but the method of escape from it is by the recognition of the measure of truth in it. It is possible that bile might be secreted without a liver and entirely probable that thought can exist without a brain; but in the case of man, the organ we call a brain is the evidence appealing to the senses of the existence of those marvelously complicated acts which make up the soul-life in man. When we view an object in a glass, at the same time looking at the object itself, we need not be surprised that the movements of the image are synchronous with those of the object nor invent theories to account for the explanation of the conformity observed. Still less do we seek to show that movements of the image in the glass cause those of the object itself. And yet the common attempt to indicate how the brain produces thought is not more absurd than the suppositions mentioned.

The theories respecting the relation between the soul and body are, of course, much influenced by the view entertained as to the intrinsic nature of the two subjects of thought. For those who regard body and soul as distinct and disparate entities, a difficulty at once arises in accounting for the constant connection between the brain and thought. We are told that the nervous processes produce the phenomena of consciousness which we call sensation, feeling, perception, impulse and will. Still we are assured that these "psychical activities" are the expression of the life of a peculiar being which is immaterial and consequently not in space and is a metaphysical unit and so indivisible that it must be in only one place at a time, and other interesting things all equally undemonstrable and unintelligible. In some way the material body acts upon the immaterial soul to cause the latter to act as it does in the processes of thought and volition and feeling. All physical analogies here seem to break down. If we attempt to employ the analogy of the transfer of a physical force from one mass of matter to another we have the difficulty confronting us that it is insisted that the soul is as unlike as possible to the matter of the body from which the force is supposed to emanate. But by all analogy likeness is a necessary condition for the transfer of force from one body to another and it is thought by some logicians that the predicate of likeness is really only the statement in another way of the fact that the two objects compared are capable of reacting on each other. Again in the view held by the advanced school of physicists, the passage of a force

from one body to another is really a transference of the properties of the one to the other, for the properties are simply the forces resident in the individual.

Still farther difficulties rise as one proceeds, one of the most serious of which grows out of the attempt to reconcile the attribute of freedom, *i. e.*, the spontaneity of the soul's action, with the observation that the form of the soul's activities seems to be conditioned by the external stimuli which affect the nervous system. Our text books are filled with endless and usually profitless discussions intended to prove or disprove the freedom of the soul to act in any way it choses in view of given inducements. The belief that the freedom of the will requires that it should be possible for the soul to act at any time in a way determined neither by the circumstances of the environment or by the inner nature of the soul itself or by any combination or interaction of these two elements is entertained only by those who fail to see its grotesque absurdity; but the influence of some form of this dogma is felt where it would not be explicitly defended.

The analogy of the conservation of energy also gives trouble, for it is plain that if the forces which act on the nervous system from without are transformed till they at last produce in the soul the sensations, etc., to which a psychical nature is attributed, then it seems superfluous to require a separate and superphysical cause for the same act. On the other hand, if the external stimulus really has no efficiency in the production of the act of consciousness, why should the stimulus seem to be a necessary prerequisite? Force is lost in either view and this is contrary to the dogma of physics. Sometimes the conscious process is called an epiphenomenon, *i. e.*, a phenomenon or appearance not the result of the action but a shadow-like accompaniment of the activity. The difficulty also arises that we unconsciously undermine the freedom of the will in denying the element of real energy in the psychical phenomena because it is a matter of every day experience that our psychical experiences apparently issue in voluntary acts, each of which has its material effect. The theory of the reciprocal action between the soul and body, in the crude form in which it usually appears, may accordingly be set aside for the present while we consider the claims of the theory of identity of these two elements.

The claim is made that there is no real distinction between the

physical and psychical. Two forms of this theory are possible, the one assumes that matter is the only real thing and that the so-called spiritual phenomena are only properties of matter. *Materialism* finds no evidence of a second reality aside from the matter of a body. Its spirit can at most be but an abstraction or a special way of considering the properties of matter itself, which is fully competent to explain all the peculiarities of the conscious life. On the other hand, *spiritualism* replies that all that we know consists of sensations and other forms of psychical manifestation and that matter is only an unjustifiable inference. The properties of matter, such as extension and inertia, are names for the constant form of our experiences. The second form of the identity theory is more likely to appeal to the thoughtful student than the first, yet it is in several respects unsatisfying to the critical mind.

The commonest way of attempting a reconciliation of the difficulties above noted at the present time is by the supposition that the same process may have two aspects. Fechner compared the nervous and the psychical to the outer and the inner aspects of a curve. Seen from without it is convex; seen from within, it is concave. A concave line is different from a convex one, but yet they seem to be one and the same line viewed from different points of view. This is a clever illustration, but it must not be forgotten that it is only an illustration and is not an explanation. Outside and inside of a curve are mathematical ideas implying, among other things, certain points of reference or *loci* without which such a distinction as that between the outside and the inside of a curve is impossible. To press the illustration is to to be guilty of a subtle form of begging the question, for it is this difference between the inside and the outside point of view that is sought to be defined.

Let us see if we may not adjust the difficulties of this problem in a way that, while it shall not assume to offer a solution of a problem in its nature to us insoluble, yet shall leave us in a state of greater satisfaction with the practical relation of man to the two forms in which his experience appeals to him. First, then, the only absolute criterion of being we know is change or activity. A non-acting thing is nothing. Even an imaginary thing is an active thing. In our own experience of our purest acts we are unconscious of anything back of the act producing the act. We seem to will spontaneously. Pure activity without the ele-

ment of interference or resistance we may call *pure energy*. Such a form of activity is rarely, if ever, met with in human experience. All activities studied in physical science are found subject to resistance and are called *forces*. All such forces are convertible and it is a natural inference that they may be reduced to a common form. Such a primitive or fundamental form would be pure, *i. e.*, there would be no mixture, there would therefore be no interference or resistance and such a condition of force would be the theoretical pure energy (Pure Being of the philosophers). *Materiality* is an expression of the forces in more or less permanent equilibrium in the individuals of experience as entering our senses. The degree of complexity of such equilibrium is various and this variety expresses itself in a series of successively "higher" properties. In living matter the coördination is very extensive and complicated, and the equilibrium very perfect and tends to be self-perpetuating. The various degrees or grades of consciousness are expressions of successively higher forms of the coördination. Such expressions in our experience are found linked with the vital equilibrium of individuals, and the cycle of psychical evolution is connected with and bound up in the cycle of vital evolution, yet there is nothing to prove that the psychical need be restricted to the association with the individual with which it is now associated. It is conceivable that the psychical differentiation should acquire connections with other forms of body.

To sum up this discussion: It is not true that the soul and the body are disparate and wholly incapable of reconcilation, for they are different expressions of force associated as parts of one system. It is not true that the two are identical, for they differ in form and this difference is of a nature to distinguish the physical from the psychical *toto cœlo*. It is not true that the one is the outside and the other the inside of the same curve; they are not different aspects of identity, but they are parts of a single system and so intimately related, but being different in form they are in that fact different in essence. It is to be expected that the ideas presented may seem obscure because of their unfamiliarity, but the thought is after all the simplest form of an expression of the results of unsophisticated experience.[18]

[18] On this general subject cf. also "Recent Contributions to the Body-Mind Controversy," *Journal of Comparative Neurology and Psychology*, vol. 14, no. 5 (September, 1904); and "Mind and Body—The Dynamic View," *Psychological Review*, vol. 11, 1904, pp. 395–409.

THE CONCEPT OF INDIVIDUALITY

The greatest difficulty the dynamic philosophy encounters is that involved in accounting for individuality. If all energy is bound together in one universe, all being parts of the whole and the whole felt or implicate in every part, how does the part become discrete? The reply is simply that creation is the introduction of mode (diversity, heterogeneity), and so far as our universe is concerned this diversity is primary. Given rhythmical variation and it can be conceived (from physical analogies which we may accept as valid) that two centers of activity may impinge upon one another in an infinity of ways whose one limit is identity and whose other limit is opposition. The results of such interference will conceivably vary also through an infinity and these resultants will be modes of activity differing from either of the primary energic modes.

When a certain number of energic centers or factors are brought, after successive trials and selections, into certain mutually harmonious phases, these may become bound into a syntheticum or inferior organism which realizes our concept of individual. Let us suppose, for example, a more or less uniform stroma or energic field within which are playing a variety of forms of energy. This, let us say, is the plastic magma of a granite. Now certain of these forces become correlated by virtue of coherencies in mode and there arises a crystal of feldspar, *i.e.*, a certain definite aggregate of activities expressing themselves as properties to our senses *via* our scientific apparatus. The energy has become less facile, and has become compounded into a more permanent form. There were reasons for the tendency for this particular appearance in the total formula of the energy in the magma, and not one but many crystals were formed; there was a sort of feldspathic epidemic. Now the newly formed units or freshly crystallized individuals exert their reactionary energy on the magma and tend to absorb all of the appropriate forms of energy to themselves. The crystals grow. At the same time they negatively tend to polarize the residual energy in the magma and new units of synthesized energy appear. The new syntheticum may be horn-

blende. What remains develops certain harmonies, and quartz envelops the preformed elements filling the interspaces. The "molecular" energies of each of these ingredients combine to form most resistant and permanent elements. Of course there is constant reaction. There is tension between the elements; there is chemical, thermal, electrical interaction, and many others of which we know nothing, and it is impossible to deny that the quartz is in constant energic communication with elements in Sirius. This "social" relation is no bar to a high degree of individualization.

In the crystal there is the power of assimilation and reproduction. New little crystals of perfect form are formed as parts or adherents of larger ones. There is no particular reason for denying that this tendency, however weak and limited to special conditions, is analogous to the reproductive tendency of animate beings. A *species* of mineral, it is insisted, differs from a species of animal in that the individuals forming a species of mineral arise freely, independently of any previous individual. Thus our quartz grains arise in the magma independently of any other quartz grains, while an individual of a species of animal cannot arise independently of some pre-existing animal of the same species. To this it may be replied that it is yet unproven that spontaneous generation must not be called in to account for the origin of life (if not, there is a break in evolution) and also that the all-important thing in both cases is that there shall be a certain assemblage of properly adjusted energic forms in coadaptation:—in the undifferentiated magma of the granite on one hand and in the germinal elements or buds of the animate species on the other. Inasmuch as it is demonstrable that the presence of a crystal is a determinant to the formation of others in the magma, it is only necessary to suppose that in the more complex composition of animate individuals this (at first adventitious) aid becomes finally a prerequisite. Thus the difference between the origin of new individuals in the two kingdoms reduces to a minimum.

Now, as we saw, the possibility of variation in the manner of impingement, where two forces interact, varies between identity and opposition. But it is in accordance with physical analogy that, to our senses at least, there should be "critical angles" or "genetic modes." In passing from identity to opposition, those stages of

interaction up to a certain point call out a sort of response in our senses having a likeness imposed by the fact (let us say) that they appeal to one organ. Another segment may find no access to our sensorium, and so on.

Now if these *extrinsic* reactions are capable of awakening various kinds of consciousness in the observer, may it not well be that the *intrinsic* element in each coördinated energic system may have a similar power and that it should have a like analytic form so that there should be varying forms of genetic modes corresponding to the several segments of intrinsic reaction as well as in the case of extrinsic reactions? But it must be observed that the extrinsic reactions imply intrinsic for their realization. In fact it seems that only in the form of intrinsic reactions within an equilibrated unit of energy can these genetic modes be formed. Among such, consciousness may rank—not simply human consciousness, but whatever may be possible in the way of intrinsic reaction in thing-in-itself.

The resistance which Professor Herrick postulates as equally fundamental with spontaneous energy, is the parent of individuality.[19] Individuality consists of a particular form of expression of the spontaneity through the interfering resistance constituting the record of individual evolution. The individual is a segment only of a larger arc, the illumined portion of an endless trajectory. The basis of unity is found in the vector character of reactions. The cyclical processes constituting the individual life are not inconsistent with the idea that the individual existence is a condition of equilibrium. Just as a gyrating storm may move over a given path, its trajectory obeying the general laws of cyclones, while the inner motions of the vortex are unaltered or attain an independent maximum and minimum; so the life-history has its own laws, while the inner life preserves its integrity.

On the open plains in the western desert a slender column of dust rising perhaps 150 feet in the apparently still air may be seen slowly moving at the rate at which a man might walk, sometimes pursuing a uniform path, at others suddenly turning. Sometimes this spectre hastens as though urged by a sudden impulse; again it loiters as though unable to make up its mind.

[19] Cf. "The Dynamic Concept of the Individual," *Journal of Philosophy, Psychology and Scientific Methods*, vol. 1, p. 374, 1904.

The appearance may endure for hours and may be traced for scores of miles over the trackless plain. The sand in it (that is the material) is continually changing as is the component air. The little vortex is the result of the union of equilibrated forces, and is just as much a real object as is a tree or a man. It is an individual, but its unity obviously consists in the perpetuation of a definite form of coördinated activity. The currents of air which compose it are eventually merged in the general system of atmospheric currents, and the individuality is lost. It is possible to imagine a set of intricately coördinated currents of force so adjusted as to give rise to a property which we call feeling or consciousness. The human organism is especially adapted to produce the background of constant experience across which is flung the flickering image of the passing events.[20]

In a uniform medium, as has abundantly been shown, the only condition of individuality is that of vector activity. Vortex rings serve as illustrations. The discussion of vortex atoms has brought out this peculiarity. Two forms of activity appeal to our senses; first, progressive or translational or molar; second, self-centered or vector activities. In the first case the point is conceived as moving in a right line or some other progressive manner so that the motion is indeterminate; in the second case the motion is cyclical and the center of reference is stable. In ordinary parlance, when a body falls, the motion is of the first sort, but when brought to rest the motion is transformed into the second state. The body is in a state of rest and with reference to adjacent bodies is in equilibrium.

Vector motions have a remarkable stabilizing power, as witness, for example, the gyroscope. The two classes of motion have been called molar and molecular respectively, but this perhaps involves too large a hypothetical step. The crude illustrations used may serve to show at least that the same force may have a conservative power in one phase and a dispersive power in another. But let one take the still simpler illustration of a solenoid. A current of electricity passing through a straight wire produces, it is true, an induction-effect on the neighboring metals; but, when the same current is forced to pass through a spiral path, the complex acquires

[20] Some of the pages which follow have appeared under the title "The Nature of the Soul and the Possibility of a Psycho-mechanic," in the *Psychological Review*, vol. 14, no. 3, May, 1907.

an individuality—it is polarized as a whole and acts as a magnet. Similar solenoids react against it, and a system could be formed from innumerable solenoids in equilibrium which would vary with the currents sent through the several elements, while the entire system would be in equilibrium at all times. While it is not suggested that the brain cells are solenoids or anything of so crude a nature as that, yet it is believed that the afferent currents passing into the cortex produce in more or fewer of the brain cells a system of intrinsic activities which react, each with each, in a total cortical equilibrium which for each instant is the dynamic aspect of a state of consciousness—an act of mind. The whole involved activity, now more now less, at any given moment, is equilibrated and forms a self-centered process of unitary nature. The structural mechanism of the brain is an uninterrupted flux of activity of a vital character. Vital activities are all analogous, rotational or vector, we might say (for illustration solely) as contrasted to translational or indeterminate or progressive activities. To be more general, what we call structure is evidence of statically condensed energy (energy in vector states) and this is competent to enter into reaction with afferent impulses and convert them into vector activities. The sum of the equilibrated activities in the body form its vital continuum. One phase of the equilibrated continuum is the activitity of consciousness. So far as we know, the conscious continuum is associated with the total vital complex. It is not proven that any other form of equilibrated vector forces is capable of assimilating the afferent stimuli and converting them into similar terms and so converting them into a conscious activity, though it may be said that we know of nothing to the contrary.[21]

One moves a lever upon a friction-clutch, and tooth engages wheel and band moves upon pulley, till the whir of a thousand wheels follows. Could we think of the friction-pulley as gradually creating the machinery of the mill out of existing energy in resisting phases, we would have a rough image of the vital organism.

But do you mean that my foot is part of my soul? Yes, I mean that the vital activities in my foot form part of my vital

[21] Cf. "Mind and Body—The Dynamic View," *Psychological Review*, vol. 11, espec. pp. 406–409 (November 1, 1904.)

equilibrium and, in so far as these contain conscious participants in the stream of consciousness, they form part of the soul. But, if I amputate a foot, do I mutilate a soul? Certainly, though it may be better to enter into life maimed than to retain a foot and go elsewhere. By cutting off a finger a child's soul may be maimed of musical faculty. There are organs, the amputation of which affects the entire character for life, and one does not willingly dispense with the frontal lobes of the brain even if he does not know precisely what purpose they serve.

On the other hand, it is possible to add to the sphere of the vital activities, as when I place spectacles upon my nose or apply my hand to the throttle of a locomotive. Where, then, is the limit of self? It is not for me to draw it. I will not cut the narrow isthmus of flesh which connects me with my twin—the universe. The ancients believed that the eye shot out rays to grasp the objects of the visual world. What tentacula has not modern science produced extending from all our organs to the phenomenal world?

But if we may not define the outer limits of the individual life, do we not destroy individuality? Only seemingly, for we need not despair of locating its center because the periphery of its sphere of activity is indeterminate. The leaven of life may be small; but, given time and appropriate conditions, it will leaven the whole lump.

Our analogy of the vector motions carried out would lead to the conclusion that, wherever such a center originated, it would tend to assimilate to itself all such activities as are capable of offering resistance to it and would, by virtue of the form or mode of its activity, cause allied activities to accumulate in harmonious adjustment about it, enlarging, and, at the same time, intensifying the energy in the original equilibrium.

Disturbances of this equilibrium there will be, but it will be one of the hardest things to exterminate we can imagine, for it is entrenched in one of the most recondite energic conditions of the universe. Seed may be dried for years in the tombs but it will still germinate. No persecution ever succeeds in stamping out a vital truth. It is not to be wondered at that humanity has enduring faith in a life eternal, but this is not the life of the soul, if by the soul we mean the "stream of consciousness." In so far as our life as a whole fits into the complicated sphere of

the universal life it will be imperishable. Maimed and crippled it may be, we crawl over the threshold of one world into the fresh glory of another, but if the life be really there, it will have no difficulty in assimilating to itself a body fit for its use, as the acorn finds its own body in the crevices of the rock and builds it forth in strict accordance with the pattern set on the peculiarities of its own vital equilibrium.

We need not look for pangens, biophores, gemmules, micellæ, and the like, in our study of heredity, or if we find them, we shall regard them as visible manifestations in some temporary form of types of equilibrated energy, vortices of specialized activity, specific in its form. The newt will grow a new leg. It is possible that the leg might grow a new newt if we were able to keep the conditions favorable, just as a branch may grow a new tree. There is nothing so violently incongruous as might appear in the childish planting of nail parings in the hope of raising a crop of men.[22]

The most essential element of consciousness is its *focal* character. This is precisely an *individualizing* moment. Our point of reference about which we construct the locus formula of our life may be continually changing, but it is precisely the "I" of consciousness and cannot be diffuse or extended. It is the intrinsic, self-reflected, epicyclic character of consciousness that creates individuals. It is the one and only individualizing moment. The self-point of consciousness is in essence unchangeable in so far as it is a point of ultimate reference, the standard of all realizing. Doubtless our activities might form part in a greater or social whole which might have its consciousness of a higher order (its more intricate equilibrium); but I do not see that it would follow that our consciousness would be involved in it or that the higher consciousness would be felt in ours. It would only be in so far as our activities entered into reaction with all, that *we* should approximate to a consciousness of the

[22] Cf. W. E. Ritter, *American Naturalist*, November, 1903, in which it is stated that Miss Sarah P. Monks has succeeded with the Starfish (Phatria or Linckia fascialis) in regenerating the body from simple rays. Cf. Haeckel, *Zeitschr. wiss. Zool* Bd. 30, 1878. Cf. Herrick, *Journal Comparative Neurology*, vol. 8, no. 1, 1898, pp. 26–27. (Cf. also the posthumous article by Professor Herrick, "Application of Dynamic Theory to Physiological Problems," *Journal Comparative Neurology and Psychology*, vol. 16, no. 5, 1906.)

"All;" but this would still be egocentric. There is perhaps some satisfaction in gathering those facts of our experience which appeal to our *senses* under one head—"the universe"— and the postulates of our *reason* under another and calling it "God," but the dualism is in our method, not in the subject-matter.

Of course it is soon discovered that many individuals are wrapped up in any one so-called individual and that units of a higher order (species, etc.) may be formed. But any given individual object, *e. g.*, any given man, has his own individual formula descriptive of the totality of the reactions (or shall we say the trajectory or career).[23] Here is a *species* of social ants. That species refuses to exist if it does not express itself in drones, warriors, queens, nurses, etc.; in short the individual is not the unit but the society or colony. This interdependence is such that the "species" cannot manifest itself except in these social terms. So with man. The social reaction has become necessary to the individual development. Life cannot continue without lateral reaction; most forms are diœcious and sexual relation is essential even to racial persistence of type. In like manner a tremendous range of coördinated (lateral) forces are fused in the individual consciousness. This transverse or social relation, then, is real. Our concept of a species finds its logical and metaphysical justification in the postulate of a unitary organism (cosmos), just as all other metaphysical verities must.

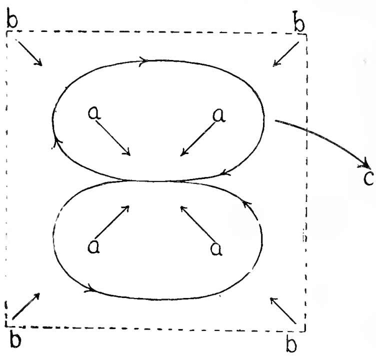


FIG. 1.

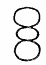
Consciousness is the individualizing moment, the intrinsic aspect of the career but not that career. Given a concentric, egocentric, or individualized motor complex capable of acting and reacting upon all other suitable complexes, one may discriminate between the inner equilibrium-stress and the reaction-phase of this energic unit. Thus the accompanying diagram, fig. 1, illustrates the locus of a certain vector force projected on a plane geometrically; *a–a* are egocentric (centripetal) forces in equilibrium

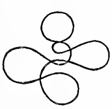
[23] Cf. *Psychological Review*, vol. 11, 1904, p. 400.

This is subject to variation as external forces, b–b, impinge on it and resultant activities (c) constitute a trajectory of the system as a whole. Now, a–a = consciousness, c = effect on external observer. In just so far as the locus formula of my neighbor is like mine and his external (environmental) elements are the same as mine will his consciousness be *like* mine. It can never be identical. The very fact that he is in another place means that his experience is $(b–b^n)_x$ not $(b–b^n)$ as mine is. His (c) will be $(c)y$ but y may be almost negligible. Now if my locus formula grows so complex as to receive the whole series of $(b—b'—b^{\infty})$, my consciousness will from time to time, or when complete, exhaust all $(a—a^{\infty})$, and your consciousness will be sensibly equal to mine, if likewise extended. Such harmony will result as will make *sympathy* complete. There will be a case when (c) is sensibly parallel to (c'). There will be no conflict in our lives. This will not make your consciousness mine unless our individuality be merged. There is no such thing as summing up the consciousness or experience of two individuals. Your career is to me a part of $(b–b^n)$. It may be in antagonistic or in concurrent mode. When nodes of your career rhythmically correspond with my rhythm, reinforcement occurs. This produces a change in my consciousness. Music produces a delightful modification of my consciousness—perhaps also of yours—but the appreciation you have does not affect mine directly.

On the above view there can be no such thing as the "evolution of consciousness" as such. One idea does not generate another. We grow and, as an expression of a given state, have a type of consciousness,—a "meaning" of that locus which constitutes the "psychic mode" for that stage.

A  corresponds to consciousness *a*

B  corresponds to consciousness *b*

C  corresponds to consciousness *c*

But (a) does not produce (b), nor does (b) produce (c). Or to be more exact, if consciousness is the egocentric (centripetal)

aspect of the successive phases, each such stage is intelligible dynamically only as a factor in the whole *A*, *B*, or *C*. Could we properly understand the matter, *A*, *B* and *C* would be but instaneous photographs or "cross-sections" of our life (career), and do not exist as such; and *a*, *b* and *c* are but intrinsic interpretations of that changing movement or transition from *A* to *B*, etc. To search for the "ground" for consciousness *c* in consciousness *b* is like finding cause for a shadow in the same shadow some time before. But the series of shadows *is* a reflex and gives us clues—our *only* clues as to movement *A*—*C*. And the reaction of *C* upon other motor-complexes will be quite different from that of *A* or *B*.

THE FUNDAMENTAL POSTULATE OF DYNAMIC MONISM

It was a geniune, if unconscious, insight which dubbed physics, on the one hand, "nature philosophy," and philosophy, on the other, "meta-physics"— an insight which seems to have been to some extent lost or obscured as a result of more rigid specialism. In last analysis it will be found that the present needs in both spheres are identical. What is wanted is a fundamental postulate on which to rear the superstructure in each department. It need not surprise us to find that, after all, this superstructure is one building of many rooms and that the foundation is the same in the two cases.

Such a fundamental postulate must needs be beyond the limits of inductive proof and it can have for its sole credential the criterion of congruousness. Complete congruousness and applicability to the conditions of all experience is all that can be demanded. In all branches of philosophy one of the most serious drawbacks to a satisfactory construction of the data employed is the absence of a common basis of reality—a fundamental postulate ontologically acceptable in all connections

Anyone familiar with modern mathematical physics does not need to be reminded that here too the present need is such a primary postulate. In philosophy students are monists, dualists, etc., but in molecular physics men seem irresistibly driven into monism. It is only when we turn from nature to the problems of subjective experience that the mind doubts the validity of its instinctive craving for unity. In saying this we are not unmindful of the fact that metaphysical dualism is strongly intrenched in the physical pseudo-dualism of matter-force. Yet, however convenient this distinction is, it does not find a place in serious modern physical speculation. The reader who has his "First Principles" well in memory will recall that Spencer frankly recognized the futility of all atomistic conceptions (pp. 51 to 53, et seq.). He is apparently unable to see any recourse in the crudely expressed dynamism substituted by Boscovich.

But we turn first to the examination of the more recent results of this speculation, in the course of which we shall not hesitate to avail ourselves largely of the authoritative review of this field by Prof. W. M. Hicks, President of the Section of Mathematics at the meeting of the British Association in 1895.[24] Dr. Hicks claims that the end of scientific investigation is the discovery of laws and that

science will have reached its highest goal when it shall have reduced ultimate laws to one or two, the necessity for which lies outside the sphere of our cognition. These ultimate laws—in the domain of physical science, at least—will be the dynamic laws of the relations of matter to number, space and time. The ultimate data will be number, matter, space and time themselves.

It would be easy to criticise this statement from a philosophical point of view. Probably the writer, if he had been using strict logical terminology, would have said, "quantity, substance and relation." That the connotation of the terms is that suggested appears from what immediately follows:

When these relations shall be known, all physical phenomena will be a branch of pure mathematics. We shall have done away with the necessity for the conception of potential energy. . . . . and—if it should be found that all phenomena are manifestations of motion in one continuous medium—the idea of force will be banished also, and the study of dynamics will be replaced by the study of the equation of continuity.

The critical reader will substitute "activity" for "motion" in the above passage, for it is inevitable, logically speaking, that the concepts of motion and force should disappear together. Such a statement from such a source should be convincing of the facts that, first, physical science will not remain satisfied short of a single metaphysical postulate back of phenomena, and, second, that the sole criterion for judging of the claim for recognition of such a postulate must be its congruousness with physical phenomena.

The history of physical speculation shows that the attempts along this line have generally shattered on the predicates of materiality and divisibility. Atomic theories date from the dawn of thought. No one needs to be told that the whole fabric of modern physics and chemistry is based on the atomic theory

[24] Those interested will find the text of the address in *Nature*, September 12, 1895.

of Dalton. It is, as history shows, no great feat of metaphysical engineering at times to substitute a new foundation without disturbing the superstructure. The theory of a rigid atom, besides failing to explain the attraction between atoms, was found incompetent to meet the requirements of molecular physics. The luminiferous ether was postulated to meet certain of these difficulties, Farraday's electrical ether to escape others, while MacCullagh's rotational ether attempted a mathematical solution. A rotational ether depends on the gyrations within for its energy. It seems mathematically possible to explain the laws of refraction and reflection by such a theory as the vortex sponge atom, but there are many objections to any form of the vortex theory yet presented, aside from the difficulty of mathematically expressing the form of motion. Thus, the problem of the density of such an atom alone is enough to disturb our confidence in the theory. Maxwell has shown that the masses of atoms on the vortex theory cannot be explained. Lord Kelvin proposed his theory of rigid vortex atoms as far back as 1867, but it has made little progress beyond stimulating to other similar attempts. The density problem has been simplified by the supposition that, just as a rigid sphere moving in a liquid behaves as though its mass were increased by half the displaced liquid, so the atom has an effective mass greatly increased by the effect of the velocity on the surrounding medium. Nevertheless we see that an explanation requiring to be so amended is no explanation at all, for we approach no nearer to the ultimate by interposing an intermediary and incongruous postulate between phenomena and the unknown ultimate. J. J. Thomson has shown how vortex rings enable us to understand the laws of a perfectly elastic atom, but no form of vortex atom has yet offered a satisfactory explanation of gravitation, which is really the crucial point in the discussion.

But we must not forget that, as already stated, all these theories require an elastic ether, or, as Dr. Hicks himself admits, "a primitive perfect fluid." However, I am assured by a well-known mathematical physicist in a recent letter that it is still considered that the ether is not imponderable, but has a certain small weight. If so, it follows that ether cannot be perfectly elastic and our search begins *de novo*.

Now, the one thing that seems evident in the maze of conflicting

speculation is that the predicate of materiality has no place in the system. The theoretical "primitive perfect fluid" is not matter—it is not force, but a form of activity whose necessary attribute is spontaneity. Such activity we have proposed to call "pure energy," ignoring for the time being the conflicting usages of that term, and it is claimed that the postulate of spontaneity is no more unthinkable than any other universal. *Undemonstrable* it certainly is, but it fulfils our one necessary condition of congruousness.

If it appears that spontaneity is logically inharmonizable with the attribute of resistance, we admit that it is indeed destructively so, but when energy is transformed into conflicting, or rather interfering, modes, force is generated, whose very essence and measure is resistance and whose laws have already become familiar as various equations of this resistance. Every instance of transformation of force involves a reconversion to energy—an equilibrium of any kind removes resistance, and energy emerges with its own peculiar attribute of spontaneity.

We submit that when the idea of a perfectly elastic medium is substituted for by that of pure spontaneity the difficulties largely disappear. Gravitation, inertia, and, in short, all so-called properties of the atom, are products of the equilibrium of forces and the energy liberated. Change of direction is inexplicable upon the theory of the conservation of forces; but if we recognize the liberation of energy in the moment of equilibrium, and introduce the element of spontaneity, the difficulty disappears. It is confidently believed that, given spontaneity, or pure energy, as the fundamental concept, the domain of physics (becoming, as it does, the doctrine of resistance or tensions) has a clear field for the attainment of the goal which Dr. Hicks points out. All on the hither side of energy belongs to physics; all on the further side of the transformation to energy is metaphysics.

Empirical psychology as a branch of physics deals with the interactions of forces, but speculative psychology is not restrained from imagining the nature of the spontaneities back of the phenomena. The prominent mathematician already mentioned writes:

I am willing to accept the hypothesis that the so-called properties of atoms, etc., are immediate and direct manifestations of divine power which created and now upholds them and that the unchanging character of natural law may be as much a necessity of that manifestation as

holiness, love and mercy are, for the essence of divine manifestation would have to be perfect good faith and certainty of action. Due responsibility could hardly be laid upon mankind as moral beings without the conservation of energy, etc.

This passage from a familiar letter is quoted as showing that it is impossible to divorce physics from higher problems. Yet it may not be amiss to seek further construction of this immediate divine in the atom. Whatever it is, it is also the element of final reference in every field of inquiry, as much as in physics. That it may and does possess many forms of manifestation is obvious; one characterization serves for all. It, if divine, is unconditioned[25]—spontaneous. If anyone objects to the use of the word divine as ambiguous, the same conclusion is reached if we substitute the word "absolute." If disposed to cling to a homogeneous ether—"a pure fluid"—its necessary attributes are continuity and elasticity. Perfect continuity and perfect elasticity, however, require two postulates, *i. e.*, unconditioned energy and infinity—both attributes of our postulated absolute. If the latter attribute be denied, we must ascribe limitations to ether, thus conditioning its elasticity and destroying its continuity. Objection may be taken to the introduction of the spatial idea. We admit its incongruity. *We* did not introduce it; but, if it be carried to its final issue, it destroys itself.

Again reverting to the necessities of our thought, it is claimed that pure spontaneity is the most natural view of phenomena and the earliest. The child perceives movement or change. It is yet to be shown that he necessarily sets up a predicament of cause. Motion is at first an event by itself as much as (and before) an object is. Motion is first observed; change is the primary psychical element and always remains so. It is just as probable that the child sets up a predicament of materiality as of cause in connection with its earliest experiences. In later life, even, our instinctive apprehension of change is of something spontaneous, as when we watch the changing hues of the sunset sky. Logical necessities growing out of the permanence of certain relations lead us to read cause into experience at a later period. We are not denying the validity of cause as a partial concept, but simply limit its application. What is now needed is a return to the naïve

[25] Not *externally* conditioned.

method of thought which accepts change as the expression of spontaneity. So only can we conceive of the operations of pure energy and universal will.

Respecting the atomic theory in general, we may say that it sustains much the same relation to the science of energy that the theory of number does to the science of quantity. The mathematics of number is of great practical convenience—is, in fact, an indispensable tool under our present limitations; but the student of higher mathematics feels that it is an inadequate, if not erroneous, makeshift for dealing with quantity as discontinuous while all quantity is really and logically continuous. So with atomic theories; they may be quite indispensable in our attempts to express the forms of kinetic manifestations, but they are all inadequate by reason of the necessary implication of discontinuity. This weakness is revealed in the fact that it has been found necessary to supplement the atom by a postulated pure fluid in which the atoms are supposed to be bathed.

When claiming continuity as an attribute of energy, of course it is not spatial continuity nor precisely temporal continuity that is meant, but kinetic or dynamic continuity—an idea already familiar to students of Lotze.

It must be left to mathematicians to decide whether the properties of activity can be construed on this basis; but we suspect that the successful solutions of problems of molecular physics will be found capable of conversion into terms of the equation of continuity.

It is true, and no disparagement, that dynamic monism is not novel—in fact it is fully as old as Heraclitus, at least. It may seem a little singular to those who know Coleridge only as a poet to discover that he was the first to clearly enunciate this doctrine in England, but that such was the fact appears in more than one passage, as witness the following:

> Space is the name for God; it is the most perfect image of soul, pure soul being to us nothing but unresisted action. Whenever motion is resisted, limitation begins—and limitation is the first constituent of body; the more omnipresent it is in a given space, the more that space is body or matter; and thus all body presupposes soul, inasmuch as all resistance presupposes action.

For some time past monistic thinking has been content, in England and America at least, to rest satisfied with a form of analytic

monism such as that proposed by Fechner, which represents body and soul as two aspects of one reality, employing the well-worn but specious comparison between the inside and outside of the same curve. The illustration serves very prettily to show the illusoriness of such distinctions, for the outside and inside of a curve are expressions disguising a whole world of foreign implications; as, for example, the relation of the curve to some arbitrarily chosen locus and the simultaneous relation of two other points which are also observers or reference data—in short, the pretty illustration involves the whole machinery of descriptive geometry, without which the meaning of "aspects" would disappear. In precisely the same way the illustration when carried into psychology implies a complicated system of ontology thinly disguised under an apparently naïve appeal to experience. Returning to the illustration, the only idea of curve suited to the conditions of our problem is that which regards it as a trajectory and discovers in it the equation of force and resistance—spontaneity and limitation. At this point the idea of resistance inevitably gives trouble, as it always has and always will. On this head it is sufficient to note that unity of source of energy does not necessarily imply unity or monotony of form. Energy as infinite can but be self-limiting. The self-limitations of the Deity are *ipso facto* creative, *i. e.*, creation is the translation of energy into force.

Quite recently Professor Ostwald of Leipzig has appeared in the field as a champion of dynamic monism and has effectively presented its claims in an address at Luebeck which may be familiar to most through the translation which appeared in "Science Progress" for February, 1896. He said:

> "If it [the mechanical construction of the universe] appears a vain undertaking, ending with every serious attempt in final failure, to give a mechanical representation of the known phenomena of physics, we are driven to the conclusion that similar attempts in the incomparably more complicated phenomena of organic life will be still less likely to succeed." "We must give up all hope of getting a clear idea of the physical world by referring phenomena to an atomistic mechanics."

In the opinion of the writer, we shall never make much progress in the interpretation of the fundamental nature of consciousness and its correlates until we frankly recognize a dynamic principle underlying the whole.[26]

[26] Cf. "The Passing of Scientific Materialism," *The Monist*, January, 1905.

PURE SPONTANEITY

Distinctly Lotzean in its derivation though not in its immediate formulation, is Professor Herrick's doctrine of pure spontaneity. Activity or energy, he says, is the fundamental category of experience. Reality consists in the standing in relation of things and this relation is dynamic. Realities are not simply thought together; they work together.[27] The earliest method of intuition or knowing is also the most accurate. It consists in the recognition of action or change, that is, a doing, as the fundamental fact of experience.

The very simplest concept of reality and the first to develop in the mind of the child is pure spontaneity from which it is the work of all later education to drive him as far as possible. The child is near the appreciation of the "Absolute" as heaven is near us in our infancy. To the child the trees just wave of themselves and he recognizes in himself similar spontaneity; but when the idea of cause is introduced it is quite as likely that the child will think of the trees causing the wind to blow as the reverse. Causality is imperfectly understood energy.

Later life is so sophisticated by the interpretations of the experience of life that language has but few relics of the primitive idea of being as simple action, as in the expressions, "it rains," "it blows," and these are mostly cases where the application of the idea of special causes is difficult or has been late in arriving. To the child "it mews" and "it barks" just as, in the language of the savage, "it thunders." We begin, as the child does, with the fundamental conception of activity. When, if ever, we are able to say something definite about the hidden ground or reason for change it will be time to speak of the thing that acts.

Our knowledge of the existence of things or events is due to changes in consciousness, *i. e.*, to activities. All we know of the external world is in the form of changes in our being. It is true

[27] Cf. "The Dynamic Concept of the Individual," *Journal of Philosophy, Psychology and Scientific Methods*, vol. 1, 1904, p. 377.

that the technical jargon of science, as well as everyday language, seems to imply the existence of what are called material units or atoms. Modern molecular physics, however, has found that the attempt to analyze the nature of such units destroys them and is returning to the naîve concept of childhood that forces simply *are*, and require no separate explanation of their "areness." In other words, the tendency in physics is to identify being with activity.

Ontology has not been more happy in its search for "substance" —the metaphysical somewhat that stands under and explains all being. This search may be frankly abandoned as futile, for it has not proven possible to avoid a final admission that the ultimate cause of all being resides in the purely spontaneous activity of an absolute Being and nothing has been gained by ages of dialectic in the effort to interpose various steps between this force or activity and its expression. It is better therefore frankly to admit that human thought can go no further than to assume the existence of such a spontaneous activity as the source of being, and accordingly bend our efforts to the task of attempting the analysis of the form and mutual relations of the several expressions of this energy.

Modern molecular physics and chemistry as expounded by such men as Lord Kelvin and Professor Ostwald throw into strong relief the insufficiency of molecular hypotheses whose postulates require one to accept at one and the same time the doctrine that force is inseparably associated with material elements and that these elements are capable of acting upon one another over unfilled space, or that the same imponderable ether is capable of conveying infinite quanta of forces without offering resistance to moving masses of matter.

It is not true that matter and force are in perpetual partnership, one being passive, the other active. Modern science knows of no such thing—can conceive of no such thing—as passive matter. The properties of matter by which alone it can be known are all forces in action. Impenetrability is an expression for molecular bombardment of opposing force. Energy is the one permanent indestructible element in our thinking. It is claimed that matter is indestructible, but this merely means that when, for example, the various forces whose common name in our nomenclature is gunpowder change their form, their exact dynamic

quantum may be detected in other states of aggregation. The periodic law of chemistry suggests a rhythmical association of those forces associated with what we call elements and points to a common basis for all these forces.

HISTORICAL SETTING

There have always been those who apprehended being thus simply—*Aristotle* is the first of the Greek philosophers to grasp the dynamic element in ontology and it is even with him only imperfectly and at times contradictorily expressed. He is sufficiently under the influence of the natural philosophers to cling to the fourfold division, even when it had no significance in the system. In like manner the dualism which appears in Aristotle's classification is purely formal and is a dualism of method and not of reality. Form (eidos) is essence and that alone which can be truly said to be. Matter has only a relative reality as a potentiality in the essence. The thought seems to be very like that expressed by the writer that energy self-limited is creation, or spontaneity is transformed into terms of the universe by the introduction of resistance. Relatively, says Aristotle, matter is non-existent. It is the opposite of entelechy or Aristotelian form which is, as Goethe calls it, the *That* or *actus*. The idea of pure matter is an abstraction. He shows great scientific insight in adding that form is at once form, end, and moving cause. That is, form is a determinant based on activity—it is the form of the activity which causes the form of the substance. Motion is the passage of the potentiality (of the energy) into reality. Aristotle's actual cause is a pure dynamic spontaneity. The first mover must be, he says, one whose essence is pure energy, since, if it were in any respect merely potential, it could not unceasingly communicate motion to all things; it must be eternal, pure, immaterial form, since otherwise it would be burdened with potentiality. Being free from matter it is without plurality and without parts. It is absolute spirit which thinks itself and whose thought is thought of thought. This eternal *prius* is evidently spontaneous and self-actuating and the essence of his being can only be energy. He clearly recognizes the doctrine of immanence and yet the resulting idea of design is limited by the obstacles offered by matter. Remembering the definition of matter, we see that the limitation is inherent in the realizing of the potential, that is, it is a self-limitation essential to the

expression of the universal in terms of the individual. In like manner the soul is a spontaneity in so far as not trammeled by its setting. As the *entelechy* of the body, the soul is at once its form, its principle of motion, and its end.

In later times *Thomas Aquinas* is the first to reiterate the position of Aristotle, but with reserve by reason of the influence of the church, to whose authority he bowed in matters of apparent discrepancy. God exists as pure immaterial form, as pure actuality, wholly free from potentiality. It is plain that the phrase "free from potentiality" means that the inherent energy is pure spontaneity and non-conditioned, for it is added that he is "the efficient and final cause of the world."

"Ea res libera dicitur, quae ex sola suae naturae existit et a se sola ad agendum determinatur."—*Spinoza*. The true idea of freedom of the will lies in the absence of or inability of external coercion to prevent the expression of the nature of the free subject. *Spinoza* is evidently greatly indebted to Aristotle. Yet he loses much of the cogency of the older writer by failing to make the dynamic element explicit, and by a spurious mathematical form. He says, however, "God acts only according to the laws of his nature, constrained by no one, and hence with absolute freedom, and he is the only free cause." As a cause God is immanent.

In *Leibnitz* the dynamic element is fully recognized. Active force is the essence of substance. The doctrine of monads adds obscurity rather than intelligibility to a grand concept. The energy which is the essence of monads is intelligent and where the force is equilibrated or reflected upon self the subject becomes conscious. The principle of continuity necessary to any system of nature is derived from the concept of motion; but in reality it is not motion but energy which constitutes essence and it is this alone which remains constant. Extension is not predicated of the monad and position is only used in an illustrative way. Activity and limitation are the elementary conditions of individual being.

Lessing elaborates these ideas and says that thinking, willing and creating are identical in God.

In *Herbart* the dynamic element is most clearly developed and it is to this fact that Herbart's utility in pedagogy is chiefly to be ascribed. Herbart says that the soul is a simple, spaceless essence, of simple quality. The intellectual and in fact all psychical phenomena are reactions in opposition to disturbances.

(He might have added, of equilibrium.) When several such responses arise, they fuse (again in equilibrium). The soul's acts of self-preservation are ideas. That is, the form which the pure spontaneity of the soul takes in returning to equilibrium from impact or limitation is intelligent.

Maine de Biran among later French philosophers most clearly formulates the dynamic position.

> "Effort made by the will and directly perceived, constitutes the ego, the individuality, the primary fact of the inner sense." "The idea of force is the corollary of that of effort." "I will, I think, therefore I am . . . . I am not a vaguely thinking thing, but a definitely willing thing, which passes from will to action by its own energy, as it resolves within itself or acts beyond itself."

The idealistic mysticism here needs to be qualified by an explicit identification of being in general as action and a proper recognition of spontaneity as a function of all unconditioned effort.

The unfortunate polemics of *Schopenhauer* have blinded many to the force of the masterly argument in his *World as Will and Idea;* and many read the poetry of Coleridge without penetrating through the wordy husk to the philosophic truth it seems to obscure rather than reveal. Schopenhauer says, for example,

> "The true being of matter is its action, nor can we possibly conceive it as having any other meaning. Only as active does it fill space and time." "Cause and effect thus constitute the whole nature of matter; its true being is its action."

Goethe, who was a dynamic monist so far as he was a philosopher at all, recognized that "Im Anfang war die That."

ENERGISM: THE FUNDAMENTAL PRINCIPLES OF DYNAMIC REALISM[28]

Energy we define as the pure spontaneity of activity, while force is the same activity under limitation, as we meet it in our experience. We have to do with force and postulate energy only on grounds of logical necessity. Common sense revolts at the idea that the objects about us are not real, and the position above indicated is easily misrepresented as though it were maintained that there is no such thing as a real being apart from the process in my mind which brings it into consciousness. We are assured of the reality and objectiveness of the stone wall because of the uniformity of our experiences and the conformity of the testimony of others. What we deny is that the reality of the stone wall is any greater for adding the undemonstrable idea of material elements in the wall. Certain forces acting with uniformity in definite relations form the only basis of reality which psychology or physics can afford.

Experience is a name for the changes which take place in our conscious selves. There may be many changes in the surrounding world and in our very bodies, but none of these is a part of experience until it has made itself consciously felt. Changes in our brains and in the current of our physical organism otherwise may produce alterations in the subsequent course of consciousness; but only when these conscious alterations actually appear can they be said to have entered experience. The most careful analysis which physics has been able to make of the phenomena of the physical world has resulted in nothing more than the discovery of a great variety of forces operating in the field of our experience. *Force* is simply a name for anything that affects experience. Comparatively few forces are thus known directly, but in most cases the force is inferred from the interpretation of indirect effects of forces on experience. We may think of the rays of light impinging on the retina as forces directly affecting

[28] Cf. "The Passing of Scientific Materialism," *The Monist*, January, 1905, pp. 46–84.

experience and of the light rays gathered by the microscope as instances of forces indirectly affecting experience. A moment's reflection, however, will convince anyone having the slightest familiarity with physiology that the first instance is a case of exceedingly round-about affection of consciousness; for the refraction in the lense and the phenomena of accommodation in the eye are but the first steps in an extraordinarily complicated process before the forces can reach the organ where they are said to "enter consciousness." We see then that the organs of sense are simply devices for so adjusting the forces of the surrounding world that they shall produce definite and specific kinds of experience. All scientific apparatus is simply added apparatus with which the ingenuity of man has supplemented the original natural endowment.

The organs of special sense are adapted to cause the experiences that come to us through their mediation to appear externalized. Recent experiments show that a person who wears glasses so adjusted as to invert the field of vision will soon come to see the world as before, right side up, proving that the conception of position and relation in space is due to a reaction between the experiences of the various organs of sense and that is it not a direct "intuition." Experiences which reach consciousness through other channels do not have this peculiarity of external reference and seem to belong more directly to us. This distinction is not a primitive one and to a man born blind who suddenly receives his sight the visible world seems to rest on the eye just as the felt object rests on the finger tip.

The distinction between subjective and objective arises very early and becomes a most important element in psychological analysis, but it must not be allowed to prejudice one in the belief that there are any kinds of force known to us otherwise than the simplest forms of experience are known, *i. e.*, as affections of consciousness. Those forms of force which appeal to us through the avenue of more than one sense with special constancy and acquire the element of localization have attained in our experience a very special coherence and reality, so that the appearance of one of the data from a single sense suggests or revives the data from the other sense and the feeling of reality remains. This reality is thought of apart from the sense data and gives rise to the idea of *substance* or a reality beneath and supporting the

appearance. This same reality-idea when applied to the acts that are recognized as such and are plainly forces rather than objects is termed cause. When the reality idea is applied to experiences that prominently affect the sense of touch so that the tactile or muscular sense-element preponderates, the substance is called *matter*. No doubt the most of us recognize matter in forms of experience in which we have not appreciated any tactile element, but these are refinements of a sophisticated science.

One great gain from this form of apprehension of reality is found in the removal of a problem which has perplexed thoughtful people during the entire past, namely the property of inherence or the peculiarity of one real being which enables it to act on another. If activities are a single essence and differ only in form, they are convertible and thus any form of activity may conceivably be transformed into another and the conversion of one mode of action into that mode proper to my conscious state is a problem of interference or composition of forces, and requires no outside element or *tertium quid* to "cause" it. A rainbow in the heavens is not less a real thing than the mountain beyond it because the forces acting in the former case are evanescent and appeal to but one of our senses.

A thing or object is a concept involving, in addition to the element of reality, quality or perceived relation and the act of predicating on the part of the percipient. An object implies a subject who posits it (Lotze).

At this point is the critical stage in the development of a congruous theory of nature. Science having primarily to do in the early stages of its development with ponderable things, was founded on the idea of matter in which the forces with which it really deals were supposed to reside as properties. When these properties are removed what remains? To this question science is and ever must be dumb and makes appeal to philosophy. The rash student who ventures to doubt the reality of matter is metaphorically (if not actually) offered the knock-down argument of having his head thrust against a wall. This proves the relative impenetrability of the wall. But the modern physicist himself has questioned the sufficiency of the old position and discovers that this "property" of impenetrability is after all but the resultant of the composition of a vast multitude of molecular vibrations or forces of which we are not cognizant in their individual

capacity. The question which arises at once is, "if there are motions, motions of what?" But this is, as we have seen, perhaps simply the begging of the question. Is there any reason why a vibration must be a vibration of something? We learn of vibrations which pose for a time as essential properties of some portion of matter being transferred to some other portion of matter and there becoming properties of that object. Evidently this is a region of great obscurity which would be greatly simplified if we could think of the force as the essential "substance" and confine ourselves to the task of tracing its transformations. This in fact is the present tendency of molecular physics, and atoms and molecules are soon to be recognized as convenient words to express states of aggregation of forces. We shall proceed, so far as possible, from this point of view and in speaking of matter and organs, distinctly disavow the implication of reality in matter as apart from the expression of forces which constitute its "properties."

In like manner, we shall seek no special definition of "cause" as distinct from the force. It is the nature of force to act and a non-acting force is non-existing force. A force can be altered but not neutralized. The search for the cause of a certain event is a tracing of the genealogy of its forces.

Science has shown with a great deal of probability that forces are all convertible without loss. There are many facts which seem to show that the persistence of matter is relative and that the serial or periodic arrangement of the properties of the series of elements are hints of the dynamic progression of which they are the expression.

The physicist says he can "get it all back" without loss. But respecting transformation of energy Dr. Magnusson[29] finds that the old formulæ (all including mass with its matter implications) directly contradict the conservation of energy and introduce time-elements in electro-dynamic equations where they manifestly do not belong. His results materially strengthen the dynamic view; he cuts matter out of the dimensional equations, substituting for it energy in every case, with results which are very suggestive.

[29] "Dimensional Equations and the Principle of the Conservation of Energy," *Journal of Philosophy, Psychology and Scientific Methods*, vol. 1, no. 12, June 9, 1904, pp. 316–320.

The final stage in synthesis is the recognition of the incompleteness of the concepts of matter and force and the determination of the ground of force in pure energy. It is on this last step that dynamic monism is based. The doctrine of pure energy is not and can never be based on observation. It sustains the same relation to metaphysics as that sustained by the metaphysical concepts of inertia and ether to physics of force and matter. As a pure postulate it must satisfactorily fit and explain the observed facts and must leave no incomplete synthesis. We believe that, properly understood, the postulate of energy may serve to remove the hiatus existing between the physical and metaphysical sciences.

Anyone familiar with physics will admit that no construction of matter and force is satisfactory. The two are made to play into each other's hands in a very illogical way so that, at one moment, force seems a property of matter and, at another, matter appears as a product of equilibrated forces. Neither accounts for all the phenomena so that it is necessary, on one hand, to postulate ether which abrogates the properties of matter and, on the other, to associate with force inertia which has other characteristics than force is supposed to possess. Neither matter or force is directly presented and neither is self-evidently conceivable. We have become familiar with the terms and they perhaps have come to seem simple concepts. We are led in physics to the idea of completely elastic media, but this is obviously inconsistent with the supposed properties of matter. We should substitute the idea of pure spontaneity. If it is objected that it is not conceivable, we reply that, strictly speaking, all of that class of predicables are inconceivable. Activity not residing in matter and not subject to the limitations of force becomes conceivable, if at all, just as matter and force have, by construing the relation to phenomena. The concept of pure energy—of action devoid of resistance—is necessary to the proper explanation of physical phenomena as well as the so-called metaphysical.

Philosophically the ultimate is *existence* (being). From the phenomenal point of view the ultimate is activity or pure *energy*. The two may be identified. Energy and being are one and the same. Look at the physical side. A purely elastic medium is a postulate rendered necessary by the phenomena ot radiant force. In like manner the phenomena of continuous psychical

life require the postulate of pure spontaneous energy. Again, let us enquire what phenomena are thought to require pure elasticity in the ether. They are phenomena of propagation, *e. g.*, all ponderable substances transmit various vibrations at rates depending, among other things, on the elasticity of the substance. But the rate of propagation in the "unfilled spaces" bears no relation to such elasticity. It is necessary to assume that the medium is perfectly elastic but is more or less modified by the admixture of an imperfectly elastic substance. Now we submit that upon a dynamic theory this difficulty disappears. We substitute for density, resistance and for elasticity, spontaneity. Under certain conditions of interference or resistance, forces pass from antagonistic equilibrium to concordant phases. Resistance (the criterion of force) disappears and unconditioned energy appears. This energy has no such temporal limitations as force has, and the result is the same as is conceived in the case of a vibration in a perfectly elastic medium.

It would be interesting to trace the application of a dynamic theory to inertia and allied problems, but we notice one other point. When two moving elastic bodies impinge, the bodies suffer an alteration of their course and pursue the new path with unaltered velocity. No force has been lost, nothing has been gained; yet the whole fate of the bodies is changed, and their relation to the environment Here is something from nothing—an unthinkable proposition. What is it that has produced the great change. Change of direction or position is a very real thing. It is unnecessary to take into account the molecular changes. Let the two bodies be molecules if preferred. Again, if a bell be struck by a hammer it gives forth a tone and the force is, let us say, all employed in the process. The tone will depend on the figure and structure of the bell. Whatever it is, it is a different form of force from the blow. All the force is returned, but what produces the change? The fact of change is the paramount one, yet it is unexplained. Force is transformed without loss and might be collected again; then what is the essence of the change? Our answer is that every change of force is a death of force. Force can only change by passing through its precondition—energy—and in passing through it obeys new laws. That which physics would fain explain by an appeal to elasticity is better explained by the idea of pure energy. The natural

condition of being is free unimpeded activity. Now think for a moment of two equal forces in a state of antagonistic equilibrium. Force is not a state of matter, though a state of rest is undoubtedly an instance of hostile forces. A state of rest is not a state of inactivity. In such a state of equilibrium as we have supposed there is a constant escape of force—equilibrium is only relative. But theoretically there is an instant (not of time but of state) when all resistance is removed and the two forces are annihilated as force. They are then replaced by energy, pure spontaneity. This passage through energy is, we believe, the *sine qua non* for the transformation of force. When a tower is held in place by gravitation, there is a constant transformation of force. One form in which the force issues is inertia or resistance to change. Such inertia shows that energy is continuously being converted.

The concept of ether reduces under strict analysis to energy. The laws of elasticity, which Maxwell assumes are not those of ordinary matter, may be taken, in so far as they go, as descriptive of the nature of energy. This is the perfect liquid of Kelvin. Hinton says:

> It can be proved that it [this elastic ether] possesses the properties of a vortex. It forms a permanent individuality. . . . . The consideration of four-dimensional rotations shows the existence of a kind of vortex which would make an ether filled with an homogeneous vortex-motion easily thinkable.

Vortex-motion may be most complicated and may generate high degrees of independence and give rise to properties which cannot be represented in terms of molar motion. This type of equilibrated motion has its highest expression in forms of consciousness. Intrinsic, as contrasted with extrinsic, phenomena belong here. The higher (4-N) dimensions are non-molar and intrinsic.

THE POSTULATE OF RESISTANCE

Energy is known and can be known only by its form or mode. Behavior is the thing. Dynamic realism definitively abandons the search for the unknown ground of behavior and claims that for any human philosophy the activity itself is the ultimate.[30]

But this energic form or mode may be viewed in two ways. All activity in a world of reaction expresses itself in two classes of modes, one of which we may call intrinsic, the other extrinsic. This is the direct result of a law, which is clear enough from the popular side, but has hardly been sufficiently appreciated in philosophy; namely that activity is meaningless without resistance. Any expression of energy *in a universe* is dual in its manifestation. We could perhaps imagine, or at least, speak about unimpeded energy or "pure spontaneity," which would possess only an intrinsic mode. But its meaning would be for itself alone. No such *manifestation* of energy is possible. Physically, action and reaction are constantly associated and equal. A single or isolated force is impossible.[31]

Is there difficulty in this concept of "resistance?" Is it that an energy that has no material tag to it and "goes of itself" could not be limited? That seems a little like the idea that because "Father owns a bank he can get all the money he wants" or "Because I have a cheque-book I am forthwith rich." The self-limitation of creation settles that.

However, there is another way of looking at it. In any genetic way of conceiving of a universe any part must be implicated in the whole and the whole in every part. There must be a teleological or rational unity. This would be manifestly impossible if the energy were erratic, sporadic or variable. More closely thought out, the conservation of energy means that the doing that I now perceive is *all of it* bound up with the doing that was and that is to be. Our measures are all psychological.[32] So far

[30] Cf. *Psychological Review*, vol. 11, 1904, p. 403.

[31] *Ibid.*, p. 406–407.

[32] See *Monist*, January, 1905, p. 78.

as the externals are concerned, the various forms of force are incommensurable. There is no way to show that so many foot-pounds = so many calories. All that we mean is that these cohere in a system in such a way that such and such phenomena in one domain result from such and such transformations in the other. If twice as many foot-pounds had been found to equal the calories, we should have been in no way surprised. The point is that all energy is related to all other energy: there is an organism.

The question might be asked (in fact it has been asked):[33] "How is it possible to get the resistance or limitation necessary for the objects of our experience out of pure energy?" "Is the element of tension and opposition in your very conception of energy?"

The reply to this should be based upon an examination of the nature of the energy concept more detailed than is germane to our present purpose. The difficulty is, probably, like nearly all philosophical perplexities, a result of our unhappy logical faculty for splitting things that ought not to be divided. We may undoubtedly think of the *word*, "doing," apart from the expression, "doing of something," but it is to be doubted whether we can think of *pure* energy at all. We think by "affirming attribute." It is still more energetically to be insisted that no real severance of the doing from the thing done is permissible. It is the old matter fallacy or the cause-effect fallacy in a new guise. If energy is to be set up in the place of matter as a power behind the throne let us alone and we will return to our idols.

Viewed from a physical point of view, given no resistance to action, there is no energy. If we mean anything by energy, it must be valid in that it is acting. If the sum-total of universal energy were in like phase, it would be the same as if there were no energy so far as making a universe is concerned. Herbert Spencer has not lived in vain. Pure being is the same as non-being. We have had our Hegel. A non-acting deity would not even potentially be a God.

Practically, energy is called into and remains in existence only under condition of resistanec. Resistanec is varied and gives rise to *mode* in energy. The writer has defined creation as the self-limitation of creative power. This is not subject to further analysis. Having no experience with universal or infinite modes of

[33] *Monist*, January, 1905, pp. 85–86.

being, we do not expect to understand what we must nevertheless postulate. If this view is open to the taunt that we take out no more than we put in and so are no better than prestidigitators, our reply is ready. If other people take out of their logic more than they put in, they lay themselves open to the charge of dishonesty. The taking out of more than is put in is called in logic "fallacy."

DYNAMIC MONISM AND HEREDITY

Nearly all writers on heredity in recent times have found it necessary to postulate some form of material vital units as gemmules (Darwin), physiological units (Spencer), pangenes (DeVries), plasomes (Wiesner), biophores (Weismann). These biological units are necessarily regarded as different from the structural units or molecules and composed of aggregates of them. A few authors have, indeed, seemed to identify the biological unit with molecules, but the way in which the concept was employed shows that such identification was due to a confusion of ideas and not to any logical identification of the two elements. It is only necessary to indicate that the properties of molecules cannot rise above the nature of chemical reactions while the biological unit is postulated to explain an entirely different set of phenomena. All the attempts to cause these units to serve the purposes of heredity have served to illustrate the inherent weakness of the concept. Thus when the gemmules were required by Darwin to explain the fact that the germ in some way seems to represent the totality of the organism, he came to the absurd result that, if the gemmules were at least as large as molecules and every cell in an oak is represented in its germ, an acorn would need to be as large a bushel basket, not to mention the curious fact that every cell in every acorn would need to be represented in the germ of every other acorn.

Various forms of corpuscular emanation theories avoid this absurdity only by falling into others. Even if a fundamental distinction is made between somatic and germinal elements and a continuity of germ-plasm alone is demanded to explain heredity, the problem is not rendered more intelligible, while it must be admitted that facts seem to prove conclusively the educability of the germ. The phenomena of everyday experience tend to show that the organism is a whole and that the germ up to a definite point in its history is as much a part of it as any other cell or organ.

The solution offered for the problem of heredity by dynamic monism is as follows: The individual is a composition of cyclical

forces equilibrated in a vastly complicated aggregate of interdependent series. As in other cases of equilibrated forces there is a nucleus of energy which may be regarded as the real being of the individual. This nucleus grows out of the fact that forces in equilibrium are constantly changing and each change involves a passage through a state of removed resistance when spontaneity or pure elasticity emerges. So far as the energy is in harmonious phases we have a unitary development; so far as these conflict resistance occurs and force is evolved which adds to and modifies the equilibrium of the whole. The constant tendency is thus towards perfect adjustment of the energy, and this is accompanied by a constant change in the force-complex.

Every new influence (environmental) affects first the equilibrium of the adjacent force aggregates (*i. e.*, those of similar sort), but the change must then affect the equilibrium of the whole. The form which this change may take depends largely on the form of the existing equilibrium, so that no reaction of the environment can fail to cause a readjustment of the whole. When an organism, for example, passes from a warm to a cold climate it is not merely the integument which is altered but the whole organization is readjusted. This corresponds with what Roux means by a "struggle of the parts." From the point of view of dynamic monism such a struggle is inevitable; the balance of the organism is so delicate that no touch anywhere can fail to modify the whole. Now the germ so long as it still forms a part of the organism and participates with it in nourishment, etc., is more or less implicated in the readjustment. If we conceive the equilibrium of the organism in the form of vortex-motion, for example, it can be understood that when symmetrical partition of the figure of motion occurs for any reason, the two resulting vortices will be like vortices in opposite modes. The fusion of two such vortices would reëstablish the original motion. Minor differences could be overcome and would result in variation in the rate or figure of motion. In the simple case of organic multiplication and conjugation of entire animals this is what actually takes place. When the differences have become too great, fusion is impossible.

Now in higher animals the vortices are multiplex and yet the elements are similar and interdependent. Finally the complexity is increased and only certain vortices retain the typical form and

reflect the fundamental law of motion of the species. Such are sexual elements.

The great difficulty which has hitherto existed in construing natural selection has been the necessity of discovering some cause for variation. According to a dynamic hypothesis the core of energy constitutes a nucleus of spontaneity or unconditioned activity. The form of expression of this activity will be determined in part by the "structure" of the organism and this is dependent on its phylogeny, and in part by the extraneous impressions (environment). Unconditioned spontaneity has in the course of phylogeny become conditioned by its own past as well as the present of its environment; yet there is the element of spontaneity, and what is to be explained is not why it takes such or such a form or direction but why it does not take any of all other directions. The original unconditioned spontaneity was, then, a tendency to express itself in all ways or, in other words, infinite variability. This variability is no longer infinite in so far as the results of previous activity have precluded many forms of expression. The mathematical expression for the activity of any organism is composed of a vast number of factors mostly too complex for our analysis. Heredity is a comprehensive term for those factors connected with past activities which have modified the figure of present activity. If we could comprehend the expression for the existing activities in any organism we might hope to predict the range of its variability and the effect of changes of environment on such variability, or, in other words, the actual variation.

In attempting to understand the effect of selection one must have regard: (1) to the *status presens* of the organic activity and its cyclical alterations; (2) to the balance of element with element or part with part which will be disturbed when any new force enters the environment; (3) the direct tendency of that force. For example, a condition of darkness may directly interrupt certain visual processes and alter the circulatory and nervous equilibrium, but indirectly it may cause compensatory changes in nutrition of other organs; or the development of antlers in one part may be correlated with changes in other parts of the integument quite independent of the necessary changes in muscular control due to the added weight. In such matters as the formation of color-patterns this law may be very important.

DYNAMIC APHORISMS

The point of view of Professor Herrick may conveniently be summed up in the following list of propositions (which, however, it must be remembered were written at widely separated intervals and never revised by their author and might, therefore, have been stated differently today):

1. Existence (being) and energy are identical.
2. Energy is pure spontaneity.
3. Unimpeded infinite energy would to us seem indistinguishable from non-existence.
4. Force arises from interference of energy and implies resistance.
5. The complexity of resistance measures the quality of the force; the degree of resistance measures the quantity of force.
6. A thing or phenomenon is a manifestation of force to our apprehension and involves a thinking together or synthesis.
7. Substance is a reality or cause posited behind the thing. To the monist this reality is energy.
8. The introduction of resistance is creation. Creation is the self-limitation of energy.
9. The systematic increment of resistance—hence complexity—is evolution. There is no creation of energy, only evolution of force.
10. Matter is a subjective interpretation of forces in a state of relative equilibrium—it is imperfect or incomplete synthesis. For human beings this equilibrium must involve at least two of the forces appealing to our senses. (A rainbow is not interpreted as matter because the equilibrium subsists for vision only.)
11. All forces appealing to us in ordinary experience are either directly or indirectly associated with matter, because all these forces tend to equilibrium.
12. Vital equilibrium is the highest common form in which equilibrated forces are presented to sense.
13. Consciousness is the focusing of diverse forces upon the complicated neural equilibrium—an equilibrium of dissimilar forces of a special kind, *i. e.*, the synthesis of antagonistic forces

into homogeneous energy. It is a complete synthesis rather than a mechanical equilibrium.

14. Will is the energy so liberated.

15. Self-consciousness is the result of resistance encountered by this energy growing out of disparity between the normal modes of subjective energy and the results of the new synthesis, converting it anew into force and reflecting it. Psychologically, that is to say, self-consciousness is the reaction of the will in its expression upon the empirical ego.

16. Will is pure spontaneity in the form proper to the individual nature and is only indirectly in consciousness. As pure energy it is free (that is, to express the real being or character of the individual), but in its expression as force it is conditioned like any other force. What in psychology is termed will is a complex consisting of a variety of conscious elements,—feelings, judgments, etc.,—and sundry impulses with their trains of reflex feeling. It does not therefore obey any simple law.

17. The soul of a finite being is the totality of the energy involved in a conscious being. Its activity is not, as such, conscious. The mind—the "soul" of psychology—is the sum of the conscious manifestations. It is not correct to state that one mental state is evolved out of the preceding, for one act of consciousness has no direct connection with any other. Yet it is true that the mental processes give us the only clue to the sequence of soul processes. The conscious states are epiphenomena due to the constant becoming between energy and force.

18. Removal of all resistance would destroy all consciousness: *Nirvana.* Perfect equilibrium would make all energy conscious, as there would be a rhythmical alternation between energy and force: *Panconsciousness.* A soul can be immortal only in a resistant (responsive) medium: *Heaven.*

19. The greater the complexity of the impinging forces, equilibrium being preserved, the greater the psychical activity.

20. Forms of complexity tending to perpetuate the activity and preserve the equilibrium are pleasurable; the reverse are painful.

21. Personality is the unit of consciousness. Consciousness can never *seem* discontinuous, because that would imply a second consciousness *ad interim.*

22. We create the objective world in accordance with forms

inherent in our subjectivity.[34] The three fundamental categories or forms of thinking are mode, time and space which afford us the "this-now-here" of experience. This is the psychic present experience. The psychological past and future experience is always a "that-then-there"[35]

23. Time and extension.[36]

Time is a pregnant illustration of the tendency of the mind to effect a complete synthesis and to set up an abstraction as a symbol of the synthesis. Time is not given in experience. It is not seen to be the necessary form of inner experience until the synthesis is effected. What we really have is a series of sequences. Time as continuous is reached by the same kind of process as gives us number or quantity as continuous—a late and complicated acquisition. Every possible interpolation in the series of sequences finds the organism receptive. We are not, for example, conscious of our organic sensations as continuous; but, whenever attention is directed to them, they emerge. They are, we conclude, continuous. This is not an immediate apprehension, but a synthetic judgment. Our experience is indeed discontinuous, but various considerations lead us to fill the hiatuses. It may be added that we only incidentally become aware of the discontinuity. What then is the neurological basis of sequence? Something perhaps like the following. Vestige *a* in cell *I* awakens a certain interneuritic reaction. Upon this the similar vestige *b* is superposed without introducing any new reaction. This state affects consciousness in the manner interpreted as *identity*. Again upon vestige *a* vestige *c*, which tends to produce a different reaction, is imposed; and this change is interpreted as *dissimilarity*. The same thing is true if the cortical image be objectively caused and then repeated. If I gaze on an object and after closing my eyes a moment again view it, a sense of identity is produced. If again we superpose upon *a*, which is now a vestigial image, an objectively produced image of the same kind, *A*, the resultant is not pure identity nor is it dissimilarity. Vestige *a* has not the same penumbra of subcortically produced elements which *A* has. In the first case the presentation is *O* and in the second

[34] *Psychological Review,* vol. 11, 1904, p. 401.

[35] *Journal of Philosophy, Psychology and Scientific Methods,* vol. 1, 1904, p. 373.

[36] Cf. *Journal of Philosophy, Psychology and Scientific Methods,* October 27, 1904, p. 602; and *Monist,* January, 1905, p. 79.

$O + x$. The dog whose vestigial image is repeatedly revived is not conceived of as a series of dogs or the same dog at different times: it is simply "that dog;" but if the dog comes into my field of view, it is the same dog seen again or recognized. If I view an object in motion, it may produce one of two effects: if it passes too rapidly to be accommodated for, it produces the effect of changing position without change of time (extension). If the motion is slower, the jerky motion of the eyeball in accommodation produces a succession of images. The hiatus between these images is subjectively filled and we get the concept of continuous motion. The modalities of presentation here noticed are, then, (1) position (the act of positing), (2) absence, (3) recognition, (4) distinctness, (5) succession. In the higher sphere of judgment these become (1) existence, (2) negation, (3) identity, (4) difference, (5) time. The difference between the two categories is that one has a particular the other a general application.

A synthesis of a visual impression gives us position (place). A synthesis of several places having an identical content gives us the idea of extension and thence figure, etc. The final synthesis results in the universal—space. In time the vestigial predominates; in space, the objective. Both are, in a sense, the necessary forms of our thinking, but the necessity is not an inexplicable or arbitrary one. It inheres in the nature of the presentative process and the synthetic necessities of thought. It may not be necessary to illustrate further. We have gone thus far into detail simply to indicate the way in which the dundamental postulates are applicable to the problems of psychology and metaphysics. Everything could not be said in any one of cases cited. Enough has been said to show what further use could be made of the idea of energy.

Psychologically speaking, space is certain stresses and strains, certain tensions in the effort to move. It is a question of position with respect to my organism as a center. Our primary experience of space is angular.

Visual, *i. e.*, retinal, space is in two dimensions. Such space is closed. Our visual life is in one surface only. The eye does not shoot forth visual tentacula in search of the object as the ancients supposed.

We gain the idea of the third dimension only by going toward

and from objects. Secondarily we gauge them as they go from and approach us. The born blind, on recovering their sight, seem to lack depth in their space.

The axes of reference, fore-aft, right-left, up-down, are partly gravitational and partly anatomical, and do not express the dynamic standards actually employed by the mind (for example, in the metageometry, with its fourth and even N dimensions).

Now, says Hinton (in his book on *The Fourth Dimension*), if some hypothetical plane (two-dimensional) being should be informed of the existence of a third dimension and it were explained to him that a cube could be thought of as a square repeated in this third dimension an infinite number of times, or as a square moving in a certain unknown (to him) direction for a certain period, we get some notion of what the fourth dimension is to us who live in three dimensions.

So in the case of the fourth dimension, there may be a direction normal to all three of the known dimensions in which movement is possible; and, in the absence of the ability to make molar motions in that direction in the ordinary way, we can form no notion of the fourth dimension. It does not become a dimension or spatial element, but must be represented in temporal or intentional terms. Physical research seems to prove that there are "things doing" in nature that cannot be conceived of as done in tridimensional space, and this fact gives zest and meaning to this metageometry.

The metageometry seems to show us that moving to infinity in a radius drawn from my organism as the center of experience would be to return to the starting-point—that going far enough from self as a center would be to return—that is, the radius, after all, is but a great circle of the universe.

We call motions molar which are capable of giving rise to space conceptions. Molecular and intramolecular motions, cohesion, gravitation, etc., do not produce these perceptions directly. If the speculations with reference to vortex activity, which is supposed to give to energy the static character constituting materiality, are to be trusted, we may have in these the clue to the fourth dimension.

24. Causation as such cannot be defined, because it does not exist in the form of a plurality of causes. What does exist is such an indissoluble linking together of all realities in fixed rela-

tions as makes of the whole a complete organism, every part being implicate in every other. The complete organism is the "ground" of all being, and is the only thinkable cause.[37]

25. Reality is the affirmation of attribute. Reality in terms of experience reduces to an affirmation (subjective) of attribute (objective) and the attribute is always a "doing" or activity.[38]

Lotze says:

> We cannot make mind equivalent to the infinitive "to think," but feel that it must be that which thinks; the essence of things cannot be either existence or activity; it must be that which exists and acts. Thinking means nothing, if it is not the act of a thinker; acting and working mean nothing, if, in endeavoring to conceive them, we leave out the conception of a subject distinguishable from them from which they proceed.

On the contrary, it is impossible to conceive of a subject distinguishable from its acts or properties. . . . . The doing of things in a constant way or according to some law of action is the most real thing we know of. A modern printing-press with its bewildering multitude of activities is a very real thing, and the most real thing about it is the doing of all these correlated acts for a common end. We may say that these processes are the products of certain wheels and levers. But these wheels and levers produce their result primarily by virtue of their arrangement, the result of activities; and even the properties of the metals, to which in our search for the subject it at last reduces, prove to be activities. In fine, we discover that the printing-press, so far as we can know it, reduces to correlated activities working harmoniously to some intelligible end.

So of energy and matter, "What has our postulated material entity done to it? It has added no matter to it. It has subtracted no force from it. . . . All that remains of our postulated materiality is form of motion or activity. . . . The impossibility of discriminating essence from form or kind of activity. . . . The discrimination of essence from attri-

[37] Discussed at length in the *Journal of Philosophy, Psychology and Scientific Methods*, vol. 1, 1904, pp. 596–600.

[38] See *Journal of Philosophy, Psychology and Scientific Methods*, vol. 1, 1904, p. 377; also "The Logical and Psychological Distinction between the True and the Real," *Psychological Review*, vol. 11, no. 3, May, 1904, pp. 205–210.

bute is a psychological impossibility. . . . And . . . essence must include the past and future as well as the present of the thing."

To return to Lotze's quibble, the mind is not equivalent to the infinitive "to think," but is a *thinking thing*. It would not be thinking if it were not a thing, and if it would not be a thing if it were not thinking. Indeed, it is the kind of a thing it is because of its thinking and the only knowledge we have of a thinker is his thinking. . . . . The tone emitted by a bell when struck is the result of activity, and this tone is also a more or less constant expression of the constitution of the bell.

When I say "Lo, light!" I do not mean "Lo, I recognize light out there as an external reality." I mean "Light, a real effect, is." When I go on to say it is something out there, I have introduced the substance element. This may or may not be true, but so far as light is an experience solely, it has that about it which constitutes immediate reality: self-affirming attribute. Considered *ab extra*, as a logician, I discover that it is possible to see in this two aspects: (1) the affirming, which is essence according to the old logic, and (2) the attribute or mode affirmed. Neither of these is real, but the joining of these is the essence of reality; it is experience.

Whether Professor Herrick was a realist or an idealist is a good deal the same sort of a question as when asked concerning Lotze. Professor Herrick himself says in one of his letters in reply to a question of this kind:

I suppose I am a realist in the sense (say of Fichte) that the phenomenal world has an existence independent of the mind or that there is a world of existence independent of the mind corresponding to the phenomenal world. I am an idealist in admitting that *my* world is phenomenal, but I am not prepared to say that being exhausts itself in revealing itself to me as real. I may admit that the sun gives light only to the seeing eye; nevertheless the sun exists as an active source of the phenomenal and by spiritual parallax (judgment) I may ascertain this fact as true. The idea is not something archetypal nor does being exhaust itself in individual reality. . . . . The solution of the problem involved between realism and idealism seems to be this: Viewed extrinsically the universe is real; intrinsically, it is ideal. There is nothing in the world that has not a rational basis, and out of this grows the possibility of realizing it. To God the world is ideal. To man there is a progressive realization. Our limitations make us realists. We shall be pure idealists only when individual limitations disappear.[39]

[39] On this question see further, "The Law of Congruousness and its Logical Application to Dynamic Realism," *Journal of Philosophy, Psychology and Scientific Methods*, vol. 1, no. 22, October 27, 1904, pp. 595–603.

Let us examine the matter first psychologically. First, there is the concept of an act. Every vivid concept of action creates or borrows from the energetic side of the mind an impulse to perform the action. A second alternate action is conceived. The mind is, as it were, in suspense. Impulses to one or the other act appear with fluctuating vividness. There results a sense of suspended judgment. The energetic side of the mind is inhibited. We have the feeling of being able to do either. The concept is real rather than an imaginary one in either case. Were the conflict between the concept of jumping over the horse-block and jumping over the moon no such feeling of free alternative would exist.

The inhibition is felt as an internal restraint rather than an external coercion. Judgment having been passed upon the viability of the two impulses, then moral judgment compares the issues of the two acts with the self-ideal. One act will conduce to my physical well-being, the other will not: the one act is good, the other bad. One act will contribute to the greater welfare of the community or of an ideal abstraction ("cause") connoted with self, the other will not; the former act is right, the latter wrong. One act will bring approval of some constituted author. ity to which we owe allegiance, the other not; the first-mentioned act is lawful, the latter unlawful.

On such considerations as these one act is approved and the other disavowed. Inhibition ceases—the impulse to act, reinforced by all the added motives adduced by intelligent consideration, issues in the midst of expensive, irradiative (pleasurable) psychical accompaniments. We have performed a voluntary act approved by conscience.

I am a free moral agent because my acts are judged to agree with the demands of my being or of my character independently of any external coercion.

But was it, after all, a simple algebraic sum of various motives which my mind performed? By no means. It was more like a case of greatest common divisor, the common dividend being my character.

But could I have chosen otherwise? Yes, but only by violating my own conscience and degrading my own character. That would, however, have indicated that my character was not what I supposed it to be or was not in accord with the ideal self. I could not have done otherwise than I did being what I was. Thus arise the continual antinomies of the real and ideal self.[40]

Here we have a reconciliation of the law of determinism and the *Doctrine of Sin.* The old Hebrew idea of sin etymologically was that of missing a mark. Sinning is a mistake or failure. The concept of self increases faster than the impulses proper to its preservation. These impulses grow as character grows; but character is always behind a growing ideal, though it may be a long way in advance of a diminishing one.

Conviction of sin is possible only in a growing stage of moral life. A failure correctly to estimate the results of a line of conduct may result in our standing aghast at the results of an unconsidered act, but this does not affect the moral value of the act. Remorse is often but the belated realization of results. Such feelings are educational in effect and are substituted for in society by the punishments which form the sanctions of law. The cultured man suffers more by remorse than from any punishment, but his remorse is not capable of acting as a deterent to others.

If sinning is a mistake, where is the responsibility? Why was the act wrong? Because I now perceive that the act was not performed in conformity to the demands of my ideal nature. We say that my lower nature prevailed; nevertheless nature, since life began, has been building up these very impulses and appetites. These are essential to self-preservation. Our clearer vision now sees that they are but partial. The ideal self is larger, loftier, better. We ought to act in its behest. But, alas, it does not possess the strong body-guard of inherited impulses and requires to be guided by the clearer but colder light of reason.

[40] "Everyone regards himself *a priori* as free in his individual actions, in the sense that in every given case every action is possible for him and he only recognizes *a posteriori* from experience and reflection upon experience that his actions take place with absolute necessity from coincidence of his character with his motives. Hence it arises that every uncultured man, following his feeling, defends his freedom in particular actions; while the great thinkers of all ages, and, indeed, the more profound systems of religion, have denied it." (Schopenhauer, *World as Will,* Book IV.)

But to whom the larger self has once been revealed, any act carried out at a lower behest than this highest brings a sense of self-degradation and of shame. In spiritual evolution woe to those whose ideal so far exceeds the executive impulses that life becomes but a succession of lost battles!

Two classes are possible, saints and sinners—those who preserve the will to protect the highest self and those who consciously abandon the effort.

The controversy which has raged as to the freedom of the will versus determinism results from a mistaken idea of freedom, complicated by a perverted application of the idea of causation. As Schelling says:

to be able to decide for A and non-A without any motive whatever would, in truth, simply be a prerogative to act in an altogether irrational manner.

Leibnitz says, more bluntly, that to desire such irrational freedom would be to desire to be a fool.

Let us analyze our feeling of freedom in volition. We first must have an alternative, to be, or not to be, to do or not to do, to do this or that. The two acts compared are measured by our powers and adjudicated in this respect. We do not will to achieve what is manifestly impossible. The child but not the man cries for the moon, but the moon is not unattainable in the mind of the child. This produces a sense of alternative. The second judgment is as to the value to self, a comparison of suitability, not of possibility. The essence of freedom is in the idea that *I* may do it, not that the thing is permissible or may do itself. The idea of uncaused action violates the fundamental thing in our feeling of personal freedom. It is precisely the ego-activity in action that makes it free. The unhindered expression of self in relation to an act or, better, the act issuing in conformity to the structure of self or character constitutes freedom.

The indeterminist ignores the vital element in freedom in the search for that impossibility, an uncaused cause. Cause is an abstraction convenient as a category, but cause can only mean the immediate expression of one being in relation to another. If we conceive of a cause unpreceded by another cause, we deny prior time. Efficiency and being are the same. Even the being of the Absolute Cause, viewed as man must view it in segments, is

a sequence of causes. When viewed otherwise, as an omniscient being might view it, it is conceivable that the idea of cause would altogether disappear.

The only conceivable kind of human freedom is that which consists in the unhindered expression of self in response to external motives. It is idle to suppose that the ego could go back of self and fabricate a feeling of cause prior to its own being, or construct a mechanism for deciding behind the deciding agent. It is left for deterministic philosophers to imagine such a *deus ex machina*.

But if it be true, as Tyndall says, that

> it is admitted generally that the man of today is the child and product of incalculably antecedent times. His physical and intellectual textures have been woven for him during his passage through phases of history and forms of existence which lead the mind to an abysmal past,

then the ego is not only caused, but it is one of the most complicated webs of causation. With what made me what I am, I have nothing to do; but, being what I am, I am responsible for my acts in so far as they conform or fail to conform to this ego.

Responsibility is the strongest argument against the indeterminist position in its narrower sense. To admit that *I* am to blame is to admit that the act was chosen with reference to self. To claim that the act was directed arbitrarily by some other power than one's own character would be to absolve the only ego we know from responsibility.

THE PROBLEM OF EVIL

Why is evil permitted in the world? This is the great unanswered question in human experience. The only general answer is that of Job and the only recourse is submission to the inevitable.

For any approximate answer it is first necessary to define evil; it may be that, if properly defined, the question regarding evil would not need to be asked.

We know that life is physically over-shadowed by pain. However bright the dawn, few days lack this blighting experience, and many a life is foredoomed to drag out weary years of agony. Nothing is so real as pain. The buoyant youth strives to realize some bright ideal. All are pressing toward the mark of a high calling. But how seldom does our most strenuous endeavor achieve success. Rather, how inevitable is failure in the end. Every man is thrust into life-long conflict with a superhuman foe and acknowledged defeat from the start. Death with its unfathomed possibilities is the portion of us all.

Still again, we are all artists painting, with such skill as we possess, our own portraits. Daily we toil at the growing ideal of self. Hourly the vista of life opens before us and the universe grows large and pregnant with new possibilities. New relations are discovered and our self-ideal adapts itself to new possibilities of reaction.

This almost subconscious activity may be likened to the instinctive assimilation of self to the hero of an interesting story we may be reading. That we do not formulate such a self-estimate is because it is so fundamental a condition of our conscious life and lies as a rule too deep for words and is clothed in that modesty that is the external aspect of self-respect.

But with what a shock do we discover that in the hour of trial our self-hero fails to display heroism! We conceived our self as rescuing the perishing, but discover with shame that in an agony of fear we have pushed to their death those who clung to our garments. We conceived ourself as resenting the bribe, but find the inducement so alluring that we temporize with the tempter.

We may at last, in utter self-abasement, lay our mouths in our hands and our hands in the dust and pronounce ourselves unclean— the worst of sinners. But if character keeps growing, sinners we shall always find ourselves to be. Nothing is a surer sign of moral stagnation than the smug self-sufficiency which admits no sin. Sanctification and freedom from sin may mark the end of a holy life, for surely further growth is impossible.

Pain, failure, sin; these we call collectively evil. A stone falls on the foot and produces pain. A stone is not evil. Gravitation is not evil. But gravitation acting on a stone may produce in my foot maladjustment of processes not in themselves evil. The circulation and its concomitant nervous processes are physiologically good. It is no accident that wrongly adjusted physiological processes are painful. Natural selection has doubtless brought about this result.

The burnt child dreads the fire; it is easy to say that pain is monitory and so good, but self rebels against it as evil. We perceive that, as pleasure is not good but its usual accompaniment, so pain is not evil but its permanent concomitant. Most deep seated diseases and fatal injuries are not especially painful. Pain has developed where it has a utility to the race.

But, it is said, pain is not a guide to the correction of the evil. True, it is but a voice crying out from nature "Beware!" How our utmost soul goes out in sympathy at sight of a suffering child. We can scarce avoid raising clenched hands defiantly against Heaven and cursing the injustice that causes agony to a helpless and innocent babe.

The voice of the babe is the cry of the race. It speaks to the best in humanity, imploring aid, impelling to research. By and by a Jacob Riis hears the piteous wail of the human child, and iniquitous tenements tumble to ruin or grassy oases arise in the desert of Manhattan, or factories cease to grind out their grist of human suffering.

In a happy world there must be sorrow and pain, and in a moral world the knowledge of evil is indispensable.—*Fiske.*

Failure admits of a similar analysis. As pain indicates an imperfect adjustment, so sense of failure in the intellectual sphere is the maladjustment of effort to object. If the iron be dull and thou whet not the edge, put to the more strength. Sense of

failure is the spur which rides a good horse to success. But the goal is ever receding, the success of today is the failure of tomorrow.

He who counts himself to have achieved will train no more and run no more. Let us bury successful men, they are all dead men. What if we must all fail? How many crushed corpses were flung into the trench that other legions of the *one* army might rush over to victory?

If our self ideal is large enough, we may view life as the hero views death, a mere incident in the triumphant flow of a great "cause." Savage legends picture happy hunting grounds. Mohammed promised his followers paradise and bright-eyed houris. Christian authors have foretold streets of gold and joy unspeakable. Older religions thought it sufficient incentive to right living to look forward to such oneness with the creative Power and directive Intellect that self shall expand to embrace the all-will and the all-purpose. The insignificance of the finite is thus absorbed in the infinite and shares in its fulness.

By such scaffolding has humanity buoyed itself up under the weight of failure. Be it what it may, it is incumbent upon us, as Margaret Fuller expressed it, "to accept the universe," content to believe that while it has not entered into the heart of man to conceive of what awaits the contrite, yet finally we shall be satisfied. And do not snatch away the child's painted toy because it is but a poor image of the reality. In good time he will put away childish things.

Ah, but about sin? Surely there can be no good arising from that terrible sense of defilement which follows recognition of sin. We have seen that, for the old Hebrew, sin was but failure, a missing of the mark. The Greek had little or no idea of sin in our modern sense.

Sin is failure, but of a peculiar kind. Ordinary failure grows out of error of judgment. Our estimate of the effort necessary, for example, was wrong. The object was more remote than we thought. In sin the failure in adjustment is in the citadel of self, the will. The higher self required a certain act, moral judgment approved the act, but recalcitrant will performed another. Otherwise expressed, the ideal self which we pictured, is found not to exist, and the self we loathe is found dominant. The ideal and the actual are conflicting. This maladjustment is most humili-

ating because in the highest sphere. We could and did endure the pain we could not avoid, we expect to improve on the failure; but "who shall deliver us from the body of this death" in our inner heart chamber, with which we must live sleeping and waking?

I, the soul of honor, brave and true, my life-long hero unconfessed—I a poltroon—a cheat? No, a thousand times no; rather any pain, any failure than this. Even the outer simulacrum of this heroic ego, the man we hope others think us to be, is worth dying to preserve.

No wonder that any charlatan can gain followers if he can but persuade them that he can deliver them from sin!

Sin, the supreme failure, the extreme of pain, the crime of the traitorous self—can this also be a concomitant of good? Certainly it must be so, for no single human being has been without it.

So long as the disparity between the ideal self and the self of our present volition causes pain there is spiritual life. Happy sufferer, blessed torment, which stirs the blood of our soul to fresh endeavor! Sin-sorrows are the growing pains of the soul.

Evidently, then, no act can be a sin, though it may be a sinful act. Criminality may attach to an act the commission of which is not a sin.

To the objection that we have defined evil by denying it, the reply is that evil is truly evil to the sufferer, sin is truly sin to the sinner; but in the higher view, both are seen necessarily to belong to a general scheme the ends of which are good.

Perhaps the most fateful question remains to be asked. If we are all sinners, what are we to do about it? Must we continue to bear the burden of conscious sinfulness, or is there a way to be freed from it? We long with unspeakable desire to be free from three things: (1) our sins, (2) the sense of guilt, (3) the consequences. Almost all of religion is the outgrowth of this fervent desire. Who shall deliver us from the body of this death?

But stay: (1) all men are sinners and all men will continue to be sinners; (2) all moral beings conscious of falling below their ideal of self-perfection will feel a sense of degradation (should they feel otherwise it would mean that moral growth had ceased); (3) the consequences of this failure, primarily, in so far as they are realized, are powerful motives toward a more strenuous

endeavor to realize the ideal. The evils resulting to others are no part of our moral life except in so far as our realization of these evils affects our motives.

We come then to the unexpected result that sin, the sense of guilt, and the objective effects of sin are good instead of evil.

Distinguish between sin and the sinful act. The drunken man is guilty of no sin while committing the most shocking violations of the moral code, for he is irresponsible. With returning consciousness the enormity of his act produces a sense of guilt. In fact, he might be persuaded that he had committed crimes which had not been perpetrated at all and he would then feel all the remorse proper to the act.

The habitual indulgence in vice with no sense of guilt betrays moral death rather than sin, which was its author. On the other hand, if one sets up a false ideal, conscience may conduct a sensitive soul through purgatory for sins which seem to you or me but innocent pastimes.

But these reflections are *ex cathedra* and might be proper to a god—or a philosopher. The important thing for us, as practical men, is that every sense of guilt is an added weight to the burden of responsibility. It lays another brick in the structure of character. Should the next occasion fail to elicit from us a more strenuous effort, guilt grows. Making of our dead ideals stepping stones to higher things is no empty poetic fancy. Sin is very real. Guilt is, and no logic can avoid it. Were we all-powerful, as philosophers, we would not attempt to destroy it, but in our individual capacity our true self drives us to eternal conflict with this and all evil, and this conflict is the good.

But two attitudes are possible. The one finds us face to the front, undaunted, though defeated. There is perfect, unconquerable allegiance to the higher, larger self as it grows within us. The other attitude finds us either supinely fallen, helpless and hopeless, neglecting the ideal self, or wilfully combatting, while recognizing its demands. The world contains only saints and sinners. The change from one moral attitude to the other, whatever may be the accompanying machinery, is moral conversion. The attendant circumstances, such as the acceptance of some creed or the recognition of some savior, may be exalted above the essence of conversion. Great emotional convulsions or extatic visions may seem to be the prominent feature, but one

may see visions and not be converted or be converted and not indulge in violent emotional contortions. Some, like the child who was exhorted to seek Jesus, may truthfully say, "I never lost him."

But our definition is not that exactly of theology. It would be sufficient to reply that theology is not now our topic, yet every man is religious and religion certainly ought to assist in right living which is also the object of ethics. We go back to our question. Is there any help other than a reluctant resignation to sin and to be sorry on the little plane of our individual endeavor?

It is not in the nature of the human soul to be content with a part where every part logically suggests a whole. The social soul recognizes the existence of a vast all-inclusive unit, the ideal whole of which it is a part. If every other being has claims upon me, then my entire, perfect allegiance is due to this absolute whole. We may conceive it as design, or will, or intellect, or we may clothe it with all of our own attributes carried up toward infinity as far as our imaginations can go. Every man, be he pantheist or deist, has his god. We may, with Margaret Fuller, call it "the universe." What do you suppose her "universe" looked like?

As students of psychological ethics this Absolute assumes the form of the greatest self—that perfection of attribute and fulness of action that means the fulfilment of all tendencies and the completion of all evolution. The fitness of self to form a part in that highest union becomes the criterion of every act. The failure to realize or approach the ideal causes sharpest pain. Without this view of perfection progress would be impossible. The pull is from above. In terms of Christian theology, no man can come to the Son (the perfect exemplification of human perfection) unless the Father draw him.[41]

[41] The term "pull from above" may require explanation. It may be objected that, when the largest possible self has been attained, it is composite, a mass of efforts of the individual. Are not our highest aspirations reflected as from a heaven of brass above us? Did any one ever prove to the satisfaction of the skeptic that prayer was ever objectively answered? The objection must be accepted for what it is worth.

When the indivdual sets up for himself an independent self-existence, the only proof he has of its validity grows out of the impossibility of thinking more than one universe. If our minds were not part and parcel of other activities and bound up with all other activities in one organism, then there would be no compulsion to accept

Again, the consciousness of repeated failure, the cumulative degradation of a life of sin, is fatal to successful conquest of new ideals. The load of past sin must be removed. Stripped of all refinements of technical phraseology, the purging of the individual ideal from those defects, the creation of the new self, this is the new birth and is likewise from above. Every sin reveals a discrepancy between the ideal self and the self of experience, and such sin casts a smirch upon the ideal which must be washed away before the will can act in view of the ideal perfection. The likeness of the perfect self must be set up afresh for each new effort.

the data of our mental activities as valid. Coherence is the criterion. Yet we are not going about denying our personal existence. So later, when the *socius*-ideas arise, we discover our experiences to be one with the generalized experience of society or "society-experience," i.e., we discover that all others also have certain feelings, susceptibilities, rights and responsibilities. All of this comes to us through our own experience and the validity of the society-experience rests on the same law of coherence. But no one will deny that we are influenced by society, even though we recognize that social influence must first be reflected in our individual *socius*-sense.

Finally, when we recognize the universality of laws, when we discover that we are part of a great universe which expresses a great movement or has a vast significance, even though we imperfectly understand it, and even though we may be as pagan as Marcus Aurelius, yet this recognition of the greatest of all realities is reflected back with great power into self. We say, "O Universe, I will as thou willest."

But, you say, this power is from within. In one sense, *Yes*, but in a truer sense, *No*. It emanated from within, but it is reflected back with new power from without—from the truth we discover. It is a pull from above just as truly as the social impulses are pulls from without.

If this great meaning—this significant career or teleology of the universe be anthropomorphized and endowed with human attributes, it still is a response to human longing and its real proof is its power to cause reactions (regeneration) in the individual life and the philosophical consideration above stated that it is impossible for us to live in two universes. The going out on the part of our nature is indispensable; but, if there were nothing to respond to this going forth, there would be no "pull from above." A stone could experience no change of heart, but even the exploring dove must find land before it can bring back the olive branch of peace to the soul.

If humanity at large finds a response to its interpretive out-goings, it attempts a flight into the unknown. If it catches glimpses of design and recognizes that we are part of some destiny that embraces all, and if thereby mankind at large is helped

"Im ganzen, guten, schonen,
Resolut zu leben,"

as Goethe says, then the same law of congruousness or coherence that obliges us to believe in self and in society obliges us to recognize this greater reality and its "pull from above."

So long as we find in the universe only a hostile array of antagonistic forces thrusting us down, our case may well seem hopeless. But, not so; even in the very sense of sin there is revealed the fact that there is a helping Hand let down. It is only in the limited view that nature is a "foe to grace;" the clearer eye will discern the fatherhood of God, the suggestion of forgiveness and the promise of ultimate success, where at first there only seemed a losing fight.

Forgiveness and regeneration appear, therefore, to be facts of ethical experience. Accepting the above view, we may admit with Bacon that

> The world's a bubble and the life of man
> Less than a span;
> In his conception wretched, from the womb
> So to the tomb;
> Curst from his cradle and brought up to years
> With cares and fears.
> Who then to frail mortality shall trust
> But limns on water, or but writes on dust.

But, however unlovely the units, when we contemplate them as organic parts of the majestic pageant of history, necessary stones in the temple of the omnipotent, they are clothed with the borrowed beauty of the completed whole.

How small a value does nature place upon the individual! Life is prodigal of its forces and wasteful of its products, but with what grim persistency does nature cling to its real gains. The new organ, once developed, reappears with mechanical infallibility and, even when rendered unnecessary by change of habitat, may remain for thousands of generations as a vestigial structure.

For it is not the individual but only the species, that nature cares for, and for the preservation of which she so earnestly strives, providing for it with the utmost prodigality through the vast surplus of the seed and the great strength of the generative impulse. The individual, on the contrary, neither has nor can have any value for nature; for her kingdom is infinite time and infinite space and, in these, infinite multiplicity of possible individuals. Thus nature naïvely expresses the great truth that only ideas, not individuals, have, properly speaking, reality, *i. e.*, are the complete objectivity of the will. (*Schopenhauer*, *The World as Will*, Book IV.)

But there is another side which is much more important for us practically. As expressed by Schopenhauer, the statement may be characterized as most misleading. Our individual lives are the concrete expressions of segments of the great dynamic unity of nature without which the manifestation of the energic idea we call species or genus would be but an empty abstraction; the reality of nature is made up of just these infinitesimal units of which nature seems so prodigal. The individual is a part and a necessary part of the sublime progressive revelation of the universe. If only a link, we are a necessary link in a chain as long as eternity and as strong as omnipotence. However small our isolated value, that value is affected by infinity as a coefficient.

Still farther, it will be seen that, reflexly, our conscious life is capable of being influenced by as much of the idea revealed in nature as we are able to receive. With our growing capacity, our contact with the infinite increases beyond assignable limits. It is not too much, therefore, to say that the value of the human soul is infinite and that the measure to which we realize this contact is the measure of our sympathy.

As Fisk says:

> The Darwinian theory, perfectly understood, replaces as much teleology as it destroys. From the first dawning of life we see all things working together toward one mighty goal, the evolution of the most exalted spiritual qualities which characterize humanity.

THE SPIRITUAL PARADOX: A METAPHYSICAL STUDY OF IMMORTALITY

He that findeth his life shall lose it.—*Christ.*
The cleaving to self is a perpetual dying.—*Buddha.*

During the past few years many questions once considered peculiarly pertinent to theology have come to be appropriated by philosophy, and students of the latter science do not hesitate to apply to the critical investigation of topics formerly considered wholly as matters of exegesis the methods and laws proper to metaphysics or even of psychology.

Among these topics is the general question of immortality. Foundations have been endowed for the express purpose of securing for the discussion of human immortality the services of the most eminent minds in diverse fields.

It is plain that the propriety of such study is wholly determined by its feasibility. The belief which one entertains respecting the future life may and often does, greatly influence his present life and the use which he attempts to make of daily opportunities. But at the present time the average individual possesses no opinion, though he may entertain a hope or be goaded by ill-defined but haunting fears. It is commonly implied that no knowledge respecting that beyond the grave is possible and that faith is its legitimate substitute. As cautious a writer as Professor Paulsen says:

> For it cannot be denied that this belief (in a future life) is becoming more and more unsettled in our times; and the future will hardly succeed in strengthening it.

On the other hand, it is plausibly argued that knowledge of the beyond might unfit us for the life that now is and that our eyes are holden in order that our short-sighted vision may be the better focused on daily duties and the lesser but necessary duties of the immediate future.

> The fallacy of thinking and speaking of a future life in terms of our present limited sense-knowledge has given rise to extremely foolish

visions of heaven, and made many gentle and religious minds incredulous.—*Edwin Arnold.*

But the fact that a conclusion is deemed impossible never yet acted as a deterrent to philosophical speculation; and, even if the main question must remain forever unanswered, there remains the possibility of a closer definition of its bearings. Nor is it altogether unprecedented that sufficiently close analysis of a question has set at rest the curiosity which asked it.

In the present case humanity finds itself in the position of a man who is awakened from sleep by the cry of "Fire" to the certainty of loss of his possessions and who must make instant choice of the precarious salvage of precipitate flight. Such choice as one makes in the emergency of our illustration is not more unpredictable or more irrational than the good the average human aspirant for immortality would select to take with him into the other world, if the selection were permitted to him. Witness the ideas of various peoples as to the nature of "heaven." It will, however, be very instructive and helpful toward further discussion to examine briefly the bare conception of immortality, and especially *what it is* that should possess this property.

Perhaps the most immediate reply would be that people generally desire immortality each for his own *self*. Ordinarily it is not even felt to be necessary to inquire what this self is or what elements it contains, nor yet as to the completeness of its independence of others; but such inquiry is a necessary preliminary to any true conception of immortality.

When confronted with the phenomena of dissolution, the idea of the self which is a candidate for immortality is at once deprived of a large and important portion of the empirical self. The savage who is visited in dreams by his departed ancestor, while convinced of the reality of the apparition, is also forced to conclude that the vision lacks the corporeal presence of a living man and presents to our sense only a shadowy vestige of the bodily self once laid away in the grave or consumed upon the funeral pyre. So the consensus of humanity is that the inviolable self is spiritual; and even though this spirit be endowed with the power of assimilating to itself a body such as may be suited to the sphere within which it resides, yet, at any rate, the body which now clothes myself is of the earth earthy.

Thus early in our search we are brought face to face with the evasive problem of the relation between body and soul. Postponing this question for the present and simply admitting that our flesh and blood cannot inherit eternal life and must be left behind along with our lands and our gold, let us ask ourselves seriously for what do we desire perpetuity. Naturally they will be things which we most prize here. Sense-gratifications, appetites and passion we must be content to resign; and, if experience has been of the average sort, we may console ourselves by the thought that with such resignation we also escape the harrassing wear and tear, the pains and myriad woes incident to bodily existence. In all descriptions of the other world it is almost surprising to note that emphasis is very strong on the negative advantages—advantages which would accrue equally in the case of annihilation. There will be no more tears and no more pain over there.

But, positively, there operates the great vital law of self-preservation. We shudder at the thought of losing our identity—we cannot bear to think of being blotted out. True the daily experience of temporary annihilation has been clothed by poetry with all the honeyed praise of which language is capable—"nature's sweet restorer, balmy sleep." A very little reflection, however, will show that this instinctive love of life, as a product of natural selection, refers to the physical existence and only by a sort of analogy is made to apply to the soul.

To the young life presents itself as a career, not as a possession; there are joys to experience, victories to gain, achievements to attain, and all by virtue of the powers springing in the life of the present as the seed of the life yet to be. To think of the loss or curtailment of this career, the birthright of all men, is inexpressibly terrible. Even the mourner over the too early dead finds in the abridgment of a promising career the most poignant occasion of grief. The idea that the apparent destiny of the human career is thwarted by death is a most common and potent argument for belief in immortality. It is inconceivable, we say, that nature or God should permit such preparations to be wasted or such promises to be disappointed. Somehow, somewhere, these prophesies are fulfilled and the sun that here has its setting will certainly rise in undimmed glory elsewhere.

To the man in middle life, who has witnessed the failure of so many individual plans and the futility of individual hopes, life

becomes more and more the annex of some "cause." There are perennial things which endure and bear fruit year by year while death reaps its frequent harvests of brief human life. The individual life becomes of value chiefly as a factor in some such powerful instrument for the betterment of collective humanity.

Finally, when the forces of life are so far spent that one's participation in the "cause" becomes insignificant and the enjoyments of life cease to lure to linger in paths which no longer please, the instinct of self-preservation grows less assertive and the fear of the death agony perhaps yields to evidence like that of Dr. Hunter who, in his latest moments, "grieved that he could not write how easy and delightful it is to die." Still the thought of individuality, if it no longer affrights us or menaces with the loss of good naturally our right, appears a solemn and melancholy possibility, repellent to our feelings. Memory supplies what hope no longer affords, and it seems incredible that we who have formed so large a part in worthy undertakings should perish while the impress of our lives, by a spiritual law of conservation of energy, continues forever.

Of the kind of immortality implied in the perpetuity of effort when once exerted, there seems to be no doubt. We are intellectually convinced that our influence is immortal; but, like Kutadanta, the disciple of Buddha, we care little for any other immortality but that of the individual self. Nor does the statement of the Buddha that "he who cleaves to self must pass through the endless migrations of death, he is constantly dying; for the nature of self is a perpetual death," nor yet the word of a greater than Buddha that "he who would save his life shall lose it" cause us to subdue the craving for an immortal life in which there may be continued the memories and experiences of our present individual self.

The attribute of individuality is one which gives, and since the time of Aristotle, has given the logicians much uneasiness. In the Ingersoll lecture for 1899, Prof. Josiah Royce, in the course of a discussion of "The Conception of Immortality" devoted practically the sum of his endeavor to the settlement of this vexed question, rightly judging it to be a necessary preliminary to the broader theme.

Professor Royce states that

"our human type of knowledge never shows us existent individuals as being truly individual. Sense, taken by itself, shows us merely sense qualities—colors, sounds, odors, tastes. These are general characters. Abstract thinking defines for us types." "Even if by comparisons and discriminations we had found how one being appears to differ from all other now existent beings, we should not yet have seen what it is that distinguishes each individual being from all possible beings. Yet such a difference from all possible beings is presupposed when you talk, for instance, of your own individuality." "For I must still insist,—not even in case of our most trusted friends,—not even after years of closest intimacy,—no, not even in the instance of Being that lies nearest to each one of us,—not even in the consciousness that each one has of his own Self,—can we men as we now are either define in thought or *find directly presented in our experience* (italics mine) the individual beings whom we most of all love and trust, or most of all presuppose and regard, as somehow certainly real. For even within the circle of your closest intimacies our former rule holds true, that, if you attempt to define by your thought the unique, it transforms itself into an unsatisfactory abstraction,— a type and not a person,—a mere fashion of possible existence that might as well be shared by a legion as confined to the case of a single being."

If one were limited to the abstract and objective logic or were to attempt the problem simply as a speculative attempt to form individuals out of algebraic combinations of qualities, this would be true. But it is far otherwise when we turn to what is "directly presented by our experience." The fallacy of Dr. Royce's entire discussion crops out finally, as we conceive, in his definition of *reality*. The conclusion is that "you must define the whole Reality of things in terms of Purpose." Accordingly individuality is a conception expressible only in terms of satisfied will. "An individual is a being that adequately expresses a purpose."

Such limitation as this would imply that a sense of reality is possible only after a complicated process of ratiocination quite out of the question in most cases. We wonder whether the mother is not a "real being" and an "individual" to her babe. As a matter of fact, reality and with it individuality are among the first attributes consistent with mentality. We may insist that our concept of individuals does not wait on a philosophical analysis of teleology. Nor are we denying that in Dr. Royce's statement there is an important element of truth. When we as philosophers begin to seek the last ground of validity and to drive skepticism into its last ditch, that arch enemy of philosophy is driven out only by the recognition of a teleology or coherence in an organized

universe; but this is not how we come by realities. No skepticism ever makes a "real" any less real, nor does philosophical investigation make it more real. Nor is this statement to be dismissed as a psychological generalization out of place in metaphysics. Reality we have defined as affirmation of attribute. It implies the union of objective and subjective. The philosophical concept of Pure Being we can think of apart from a subject; but reality is a realizing, it is dynamic. We may think of the abstraction "shining" apart from the light that shines, but the light is the shining.

In this process (of realizing) a limitation of the pure spontaneity of being is implied and this produces individuality. What produces the individuality of the subject no one can say—the eye may not view itself—but certain it is that, the subject being what it is, the world can and must present itself only as a succession of individuals. Dr. Royce finds it impossible for the most gifted lover to explain why the object of his affection is unique among women; for he is able to express the height of her individual perfections, which makes her all the world to him, in no other terms than those which all other lovers use. But Touchstone had no such difficulty with his Audrey, when he introduced her as "an ill-favored thing, sir, but mine own." In a moment of candor the supposed lover might admit that some other maid might have all the charms of his Helen (he is frequently forced to hear that "there are fish as good in the sea as have ever been caught") but he is undisturbed, she is "his own." In other words, the essence of individuality lies in relation to the subject. The lover finds the uniqueness of his inamorata in the relation she sustains to him. We distinguish objects as individual because of relations between such objects and ourselves. There may be a thousand peas exactly alike, but this particular pea is in my shoe, and is a very particular and individual pea. Any other pea might be there; but, by virtue of its immediate assailment of consciousness, this pea is individualized. I realize its presence. No amount of philosophical speculation as to the lack of individualizing properties will prove convincing so long as the relation of this pea to my "immediate experience" remains what it is. The discovery of some particular fleck of color upon one out of a thousand leaves would not, as Dr. Royce shows, make of it an individual; for at any moment we might find its duplicate,

but the commonest kind of leaf now seen becomes "mine own" and a unique leaf thereby. I may thrust my cup a thousand times into the ocean and each cupful of water will be an individual till it flows back into the immensity of the infinite.

The ultimate criterion of validity is, we repeat, congruousness. We must believe that the world is an organism or we cannot begin to think, and so, as philosophers, we admit that individuals which are creatures of our experience must have an external validity; but how we are to construe the relations which are perceived as individual is a large question. It is easy to learn that the objects which we perceive as discrete lose this discreteness when we learn more about them. Their relations to us are but insignificant as compared to the relations they sustain to the universe at large. The present is but a drop when seen in relation to past and future —in fact when so compared, it is not. Individuality is dependent upon the *now*; but there is no now, only a forever.

So far from the purpose creating the individual as we know it in experience, it destroys it by converting it into continuous quantity. You cannot photograph the movement of the train—individuality is an instantaneous photograph, while purpose is the train conceived in motion; it is a trajectory. But, it is asked, Could you not trace out the single thread in the tangled skein and would not the thread, though endless, be an individual? The illustration is faulty; for really the continuity of the thread is as much lateral as longitudinal, except that we fail to perceive the lateral connections. Strict analysis might follow the lines of force in the stream passing over Niagara, though each particle is under equal pressure at all times in all directions from its adjacent portions of the stream. In this sense purpose does individualize. It serves to express the share of one part of the universe in its total purpose. Here, as before, it is an analysis imposed from the mind instead of something inherently individual.

Individuality thus appears as a limitation. We cannot conceive of existence without it, but "Where wast thou when I laid the foundation of the earth?" "Knowest thou the ordinances of heaven?" Perhaps there are things not dreamed of in our philosophy, and it may yet be true that it hath not entered into the heart of man to conceive of many things the truth of which we have no right to deny. Because our consciousness requires individualizing as a condition of its functioning, it does

not follow that consciousness might not exist in forms not requiring such limitation.

But the self which we sought to preserve would seem to have disappeared with other forms of individuality under strict metaphysical inquiry. To get at this matter in a different way, let us consider what self is. In your case and mine, what self do we wish to take into the other world; that which was our self at ten, at twenty or at sixty years? It is not the decrepit body, ready to welcome the grave, not yet is it the immature and ill-balanced self of early youth. Is there any moment of life of which we can say this is the stage which we desire to perpetuate to all eternity? Evidently there is no such stage. We think rather of the ideal self—what we dream we might be if permitted to outlive the effects of our follies and to realize the best without suffering the worst of our experience. A purified spirit in a glorified body is what we crave, but this is not immortality, it is reincarnation.

Very suggestive and illuminating is the discussion of identity and non-identity attributed to the Buddha (see Carus, Gospel of Buddha, chap. LIII). By the parable of the lights the futility of defining individuality is well illustrated. The Buddha says:

> "Self is death and truth is life. The cleaving to self is a perpetual dying, while moving in the truth is partaking of Nirvana, which is life everlasting." "Thy self to which thou cleavest is a constant change. Years ago thou wast a babe; then thou wast a boy; then a youth, and now a man. . . . Now which is the true self, that of yesterday, that of today, or that of tomorrow, for the preservation of which thou dost clamor. . . ." "Practice the truth that thy brother is the same as thou. Walk in the noble path of righteousness and thou wilt understand that while there is death in self, there is immortality in truth."

The two greatest teachers of religious truth, the Buddha and the Christ, in whose doctrines (shorn of what is obviously local color) the essential agreement is so unmistakable as greatly to enhance their intrinsic influence, earnestly strove to minimize the concept of individual immortality in the crude form in which it was entertained by their followers. The greater success of the Buddha in this direction is to be ascribed to the more favorable soil upon which his teaching fell and not to the greater purity of his doctrine. It was inevitable that the teaching of Jesus

should be distorted to the support of the complicated beliefs of the Jewish doctrinaires in stages and grades of future existence into which much of the grossness of this life was transported. Sidartha, on the other hand, had but a sect as it were of the Sadducees for his propagandists—men accustomed by contemplation to distinguish the real under the phenomenal.

Christ warns that in the other world men neither marry nor are given in marriage; that they do not seek emoluments or high stations, but are like the heavenly influences or "Angels of God;" and, while using every vehicle of expression and illustration to convey the idea of superior felicity of the other world, clearly teaches that this felicity in some way consists in oneness with God. He informs his disciples of a great gulf fixed between the other world and this, and it is legitimate to conclude that this gulf is a natural result of the extreme divergence of the two stages of existence. Far different the teaching of the Church, which carries the extreme of individuality characteristic of its relations in this life into the next world with little change. This tendency of the teachers of religion and its poets illustrates the desire for an immortality of earthy consciousness and associations.

Assuming that immortality must be of this sort, viz: a perpetuation of our soul as the thinking, remembering, and feeling function of self, Prof. William James attempts, in his Ingersoll lecture for 1897, to remove two important objections to such belief.

The first objection grows out of the psycho-physiological dictum that thought is a function of the brain. This is again the body-mind problem which we at first agreed to waive for a time.

But let us see how a representative psychologist meets this issue. In his own words:

> I must show you that the fatal consequence is not coercive, as is commonly imagined; and that, even though our soul's life (as here below it is revealed to us) may be in literal strictness the function of a brain that perishes; yet it is not at all impossible, but on the contrary quite possible, that the life may continue when the brain is dead.

The supposed impossibility of its continuing comes from too superficial a look at the admitted fact of functional dependence. But there are other kinds of function besides *productive* or *generative* functions, there are *transmissive* functions.

When we think of the law that thought is a function of the brain, we are not required to think of productive function only; *we are entitled also to consider permissive or transmissive function.*

Our brains may be transparent spots in the surface veil of phenomena, hiding and keeping back the world of genuine realities. The brain might be an independent variable, the mind would vary with it.

Consciousness does not have to be generated *de novo* in a vast number of places. It exists already, behind the scenes coeval with the world.

One argument which seems to have more weight with Professor James than he may care to admit, is the supposed value of such a theory in explaining or permitting a belief in the occult, to which he stands committed. This theory is like the Swedenborgian idea of "influx" and may be acceptable in theological circles as consistent with the activities of "The Spirit." The question here is whether the theory is consistent with itself.

Let us examine it more closely. Consciousness is assumed as coeval with the world. Consciousness is, let us say, somehow a product or rather a general mode of all energy or, at least, of universal energy. But this state of complete spontaneity or universality cannot be assumed to have any specific consciousness until limitations are imposed upon it. This limitation must be from within or from without. If universal energy be restrained from without, there is other energy not comprised in the universal energy and we are confronted by the logical fallacy of a divided universe. The limitation is then a self-limitation and consequently teleological.

The existence of modes of consciousness results from the limitations of energy which thus in certain specific forms manifests itself as sensations and the like—in short, in *thought*. If the brain is the name given to the sum of the limiting conditions or determinants of energy by which modes of consciousness arise, then the brain produces thought just as truly as anything can be produced. It is not permissive or transmissive in the sense that sundry thoughts exist behind the veil and some of these filter through, but it acts in the sense that the water-wheel generates forces. It does not create energy but it does create the mode of energy. Creation is, after all, but the self-limitation of energy.

Still, this form of expression is also more or less misleading. What we call the brain is as truly a phenomenon of experience as what we call mind,—only a step farther removed, and it accords better with the facts to consider both as correlative expressions of energic forms (life) which reveals itself in various modes, though to our direct apprehension it only reveals itself as psychic acts or modes.

Applying the necessary corrective to Professor James' theory, it appears that no gain is secured, for the kind of immortality which we crave and he proposes is not that of undifferentiated energy back of the brain and the mind but that of the modes determined, as he would say, by the brain. The naïve assurance that the brain is only a thin spot that lets consciousness through fails; for, certainly, the size and position of this thin spot must have all to do with the kinds of modes of energy involved in thought. One would not say that the shape of the orifice had nothing to do with the generating of specific energy by a turbine, for example. Otherwise, if thoughts are ready made and are in no wise determined by the brain, why do we have one? The argument is an ingenious *non sequitur*.

But with the modification that brain and thought are simultaneous expressions of life, *i. e.*, an organized self-limited form of energy having a teleological ground and a career expressed in its form, we discover two series of variables whose tie is their common relation to an existence of which they are more correctly described as appearances. From the series of thought-variables we may, by experience, learn to predict the brain-variations and *vice versa*; but it does not follow that brain-processes *cause* thought-processes. Lest we should be prematurely drawn into a discussion of causation, from which pit escape is well-nigh impossible, we may hasten to admit that causation in this sphere must be identified with coherence in a system or organism, and so becomes an aspect of teleology as in natural science it is but one form of statement of the law of conservation of energy.

But whatever be the nature of the being constituting the basis of coherence, of brain and mind, it is subject to change; thought in a connected series bound together by memory into a unitary experience or personality is not apparently necessarily continuous. Life may go on in its absence for a time. Not every kind of brain-process is continually functioning. In some sense life

which we now live has descended to us from our ancestors. Such significance as our life has for the universe is not limited to either a conscious continuum or a brain continuum. The perishing of our body may render the presumption so high as to resemble a certainty that the forms of conscious existence we now have shall cease with it, but the vanishing of these by no means proves that the teleological unit which formed the ground for these appearances has been destroyed. As well might the chemist whose knowledge is limited to what he can see deny that water exists in the gaseous state because he can no longer discover it. It can hardly be assumed that so complex and important a center of force as a man leaves no trace besides those we experience, and has no properties besides those we have discovered. The utter destruction of the life back of the phenomenal is inherently very improbable from a purely scientific point of view. Without arrogance man can claim that his advent into the world has changed the whole character of the universe. If those centers of energy which we (in our ignorance) call molecules of matter have such a high degree of persistence as to give rise to a theory of imperishability of matter—in so much that these molecules will pass through all the mutations of experimental treatment we can give them and through numerous phases and chemical compositions—it were strange indeed if the unit, "man," should be so unstable that a breath would annihilate him. An heavenly alchemy may indeed change him from one state to another as the ice passes into the clouds, but is still water.

"But" breaks in some impatient listener, "this is beside the point; what we want to know is, shall we know our friends over there?" As James says, what we all wish to keep is just these individual restrictions, these self-same tendencies and peculiarities that define us to ourselves and constitute our identity, so-called. Our finiteness and limitations seem to be our personal essence; and when the finiting organ drops away, and our severed spirits revert to their original source and assume their unrestricted condition, will they be anything like the sweet streams of feeling which we know, and which even now our brains are sifting out from the great reservoir for our enjoyment here below.

The only answer given is by way of suggestion: "It might prove that the loss of some of the particular determinations which the brain imposes would not appear a matter for such absolute

regret." With this suggestion we too may, for the present, rest content.

The second obstacle discussed by Professor James is merely that growing out of the overpopulation of the universe in event of general immortality; but this is no longer a difficulty, if the results of the foregoing discussion are accepted, even if we go to the full length indicated by the following passage from Edwin Arnold's "Death—and After:" "If the Bathybius—nay, even if the trees and the mosses,—are not, as to that which makes them individual, undying, man will never be." But, in general, we may say with the author last quoted, "we have to think in terms of earth-experience, as we have to breathe in terms of earth-envelope. We ought to be reassured rather than disconcerted by the fact that nobody can pretend to understand and depict any future life, for it would prove sorely inadequate if it were at present intelligible."

Our conclusion, drawn from a purely metaphysical consideration is not at variance with that expressed by Paulsen, in his Ethics. "*The temporal life is the phenomenal form of a life which is eternal as such.*" To the objection above urged that one does not care for an existence without consciousness, Paulsen replies:

> Well, who says that reality is without consciousness? May not the All-Real have an absolute consciousness of itself, of its essence?. . . . And who will claim that individual beings, who have a temporal consciousness, could not have an eternal consciousness.

To this we may add that so far as we know the possibility of reality in a strict sense is bound up with that of consciousness.

The practical consequences of such a view as that to which we seem driven by purely metaphysical considerations may detain us for a parting word. Our life we find is not a possession, but a career. It consisteth not in the abundance of what one possesseth. It is more than meat, *i. e.*, it is more permanent than the sensuous joys which it affords. If we may believe that the little segment we can foresee on the earth may determine the direction of the future course of an eternal life, as the aim of the gun determines the angle of trajectory of the missile, it becomes a matter of transcendent interest to see that the aim is right, if we only can be convinced by any means that we have anything to do about it. For him who does not care to enter the mazes of ethical

theory it may suffice to remember that the universal beliefs of humanity always have some justification. As Paulsen says:

> The time will come, even though not until you are on your death-bed, when one thing alone will be material to you: whether you have honestly done your work in this world, however great or small it may have been, as a righteous man; whether you have fought the battle of life as a brave and faithful soldier.

We may differ from this author in thinking that we shall not be indifferent to whether we have tasted joy and sorrow here below and may believe that we should rejoice to enter as fully as possible into the range of human experience; we may remember thankfully our victories and rejoice that we have dipped into the sea of knowledge. For is not this segment, albeit small, a real part of the whole life we are living? We may not sympathize with those who would have us depreciate the good which nature so carefully purveys for us here; but, still, it will ever be of vastly greater importance to us to feel that we have neglected no precaution so to direct our bark that, when it passes out into the night, it shall not depart from its destined course nor miss of attaining the harbor of a blessed immortality.

ETHICAL CONCLUSIONS

Ethical living passes through three stages, the individual, the social and the religious. These are not mutually exclusive but represent the form of the *summum bonum* most efficacious in each.

In the individual stage natural selection is the determinant and self-preservation is the motive. Acts are good or bad as they tend to conserve the individual existence or fail to do so. Self-consciousness emerges from the animal consciousness clothed with the armor of protective instincts and impulses derived from natural selection.

In the social stage conscious selection is the determinant and social development is the motive. Self has enlarged by continual accretions of *mine* to *me*. Family, clan, country and the great round world, successively fall under the conquest of the victorious self. Self-renunciation as the supreme act of selfishness becomes the way to the *summum bonum* or the highest good of my universe. Acts are right or wrong as they serve society or not.

In the religious stage the divine will is the determinant and self-absorption in the deity is the motive. Man becomes conscious of self as part of a universal system. He feels participation in the divine plan. He not only thinks God's thoughts after him but he wills his acts with him. "Thy will be done" becomes his supreme desire. Nature and humanity become of one family with me, not because thay are mine but because they are God's and I am God's. Sympathy is universal. Sin is no longer rebellion, it is treason. To love God is joy and to love God is to love all created things, because we see as he sees. We have participated in creation as it was and is and shall be revealed. Nirvana[42] begins on earth. The kingdom of heaven is within you. Acts are not good or bad, right or wrong, but loyal or disloyal as they conform to the *suprema lex*, the will of God, or fail to do so.

[42] The Buddhist conception of Nirvana is in one passage interpreted by Professor Herrick in these words: Nirvana is deliverance from evil. It is not a heaven of golden streets; it is not annihilation; but it is a state of unmixed satisfaction; it is permanence as contrasted with present fluctuations.